Third Crop Pest and Horticultural Report

1915-20

Oregon Agricultural College
Experiment Station
Corvallis, Oregon

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January 10, 1921

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December 13, 1920

To the President of the College,

Sir:

I hereby submit for publication a report of investigations conducted primarily under the State appropriation for the investigation of crop pests, plant diseases, and horticultural problems. (Chap. 286, Gen. Laws of Oregon, 1919.)

This appropriation was made at the urgent request of horticulturists throughout the State, and this report, the Third Crop Pest and Horticultural Report, indicates the great value of the work. I wish to direct attention to the fact that most of the articles included are statements of progress and not final reports. It would be most unfortunate indeed if the appropriation were not continued so that the investigations can be continued.

Respectfully,

James T. Jardine,
Director.

THE DECEMBER FREEZE—SOME LESSONS FROM IT

By W. S. Brown

December of the year 1919 will long be remembered as having the coldest weather in some parts of Oregon that has ever been experienced within the memory of man. In many sections minimum temperatures went from fifteen to twenty degrees below what had been considered the absolute minimum in former years. Naturally, fruit trees subjected to these very unusual conditions suffered considerably. The cold wave extended over large portions of Oregon, Washington, and British Columbia. Damage to fruit trees and small fruits has been reported from many districts.

Of our common fruit trees, the following kinds suffered most in the order in which they are given: peaches, apples, walnuts, cherries, pears, prunes, and plums. Even the wildwood trees were not immune to this freeze and oaks over three hundred years of age were killed. Ash, locusts, and several other varieties suffered. Of the small fruits, the hardy blackberries and black raspberries, together with currants and gooseberries, seemed to weather the cold conditions quite satisfactorily, in some cases losing only their fruiting buds for the coming year. The red raspberries suffered considerably above snow line, while loganberries that had been trellised before the freeze were almost universally killed down to snow line.

Of the grapes, it is surprising to see how well the American varieties came through the winter. The vines lost some of their buds but most of the hardy sorts were not materially injured, even though they were uncovered. Vinifera grapes that were under the snow withstood temperatures which were as low as thirty-six below zero. Grapes, however, that were growing upon walls of houses or upon trellises were practically all killed back to the snow line.

The extent to which our orchard trees were killed seemed to depend upon several factors, among which are the following: variety, slope, devitalized condition, immaturity of wood, and heavy applications of fertilizer. The amount of injury to individual trees differed considerably, from those that merely suffered weakened buds to trees entirely killed. During the past winter the departments of Horticulture and Plant Pathology received and examined samples of limbs, twigs, and buds, sent in from over fifty different localities in the State. In addition to this, some twenty different sections were visited by members of the departmental staffs.

These observations coupled with later study during the past summer have led us to the conclusion that there is a great deal of difference in the recuperative power of trees of different varieties and of different kinds (Fig. 1). Generally speaking, the pear has surprised us most. For a few weeks after the freeze, it looked as if pears would be almost entirely wiped out. The cambium region turned almost black, and superficial examination seemed to indicate that the trees were doomed. Nature seemed to think otherwise, however, and most of these pears have "come back," so to speak, with a loss of this year's crop in most instances, but with fairly vigorous foliage and comparatively good growth. Just how the trees have been weakened in their resistance to future cold spells remains to be seen.

In contrast to the above, there have been many varieties, especially of apples, that pushed out leaves and seemed to be getting along fairly well during the growing season, that absolutely quit in late summer. Upon investigation, it is usually found that the cambium layer is entirely killed in the vicinity of the snow line of last winter and that the bark has loosened away from the trunk of the tree. This leads up to

a further point; namely, that one must not presume that his trees are entirely free from winter injury simply because they pass through the first summer in a growing condition. Frequently, trees will push out leaves and even bear considerable fruit to maturity, only to die some-

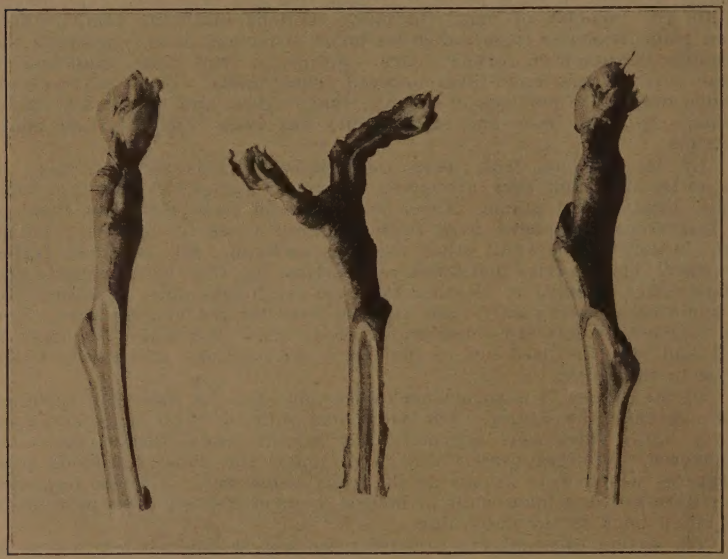

Fig. 1. Pear twigs showing darkened wood and new growth starting in the cambial region.

time during the next spring or growing season. The reason for this peculiar behavior is that the cambium layer or growing layer of tissue between the bark and wood has been so injured by the freeze that it no longer functions. The sap can be sent by the roots, as long as they can function, up through the sap wood of the trunk to the branches and leaves, thus allowing the tree to mature its crop and to appear healthy. As a matter of fact, however, this condition results sooner or later in starvation for the roots, because the digested food manufactured by the leaves has to pass down through the cambium layer to reach the roots. If this cambium layer is destroyed anywhere along the line so the tree is completely girdled, there is no chance for passage of food to the roots and the roots consequently starve. The trees, then, that quit during the latter part of the growing season or during the first part of the next year's growth do so because the root system has become so starved that it can no longer supply sap to the top.

The question naturally arises, What can be done in this emergency? The remedy will depend primarily upon the condition of the tree. When trees seem to be but slightly injured, showing this injury by yellow leaves and no fruit and small sickly buds, the first thing to do is to examine the trunk carefully in the region of the snow line. If it is found that no great amount of injury has been done to the cambium layer, then the trees can usually be brought back to normal by good methods of orchard management, including painstaking cultivation, care-

ful pruning, and possibly an application in the spring of some nitrogen fertilizer like nitrate of soda. It may be necessary in pruning to head the tree back somewhat so as to force out vigorous wood growth in place of limbs devitalized or dead. In adding nitrate of soda, four or five pounds to the mature apple tree ought to be sufficient when applied during the latter part of February or the first part of March.

Some trees will have some of their limbs entirely dead and others badly injured. In that case, examine the trunk of the tree in the region of the snow line. If the cambium is entirely killed in that region so that the tree is girdled, there is no use in trying to save the limbs above. If the trunk will come through, cut out the dead limbs and those badly injured in an effort to save that portion of the tree which is unaffected. In some cases, very sturdy limbs may have part of their bark killed. In such cases, it would be well to peel off the dead bark and drive small copper tacks into the wood as suggested by Volck and discussed by Zeller in this report, page 136. Copper salts dissolved by the rains gradually impregnate the wood and antisepticize it against heart-rot organisms.

According to Volck[1] the treatment with copper nails and tacks has been used successfully at Watsonville, California. To quote him: "The use of copper nails is the outcome of a long series of experiments in the effort to find some disinfectant which would remain effective for a very long time. Sufficient time has not yet elapsed to demonstrate what the ultimate outcome of this method will be, but it looks very promising at present. We have opened up some of the older wounds, so treated, and found no wood rot. At the same time the bark cover over the surface of the wound was developing at a satisfactory rate."

Investigations along this line, under Oregon conditions, are now being carried on by S. M. Zeller of the department of Plant Pathology, and results will be published in bulletin form as soon as the work has been finished.

It will take some time for the copper tacks or nails to impregnate the wood and so it is necessary to supplement the tacks for a few years with a paint or whitewash containing a fungicide. This whitewash should be renewed each summer. Probably the best preparation for this purpose is a bordeaux paint made by adding water to the commercial bordeaux paste or to the dry or powdered bordeaux. The mixture should be thin enough to spread like an ordinary paint. In addition to these measures for disinfecting and antisepticizing wounds on injured trees, it will be necessary to encourage all the suckers to grow around the base of the tree so that they can furnish food supply for the roots. When the limbs above have taken up the normal growth of the tree once more, these suckers can be cut out. They should never be allowed to grow high but should be kept cut back each summer.

Where the trees have been so badly injured that few limbs, if any, will be good above the snow line, or where the trunk has been entirely girdled, it will be necessary to cut back the trunk to good green wood and green bark well below the snow line. Usually suckers are found coming out at the upper edge of the good tissue. If the tree trunk can be cut down to these suckers, there is a much greater probability that it will heal over quickly than if it is cut somewhat above the suckers. In such a case, one of the best suckers should be selected for the future tree and the other suckers should be allowed to grow for some time but should be headed back so as to give the main stalk the best chance. This heading back should be done in the summer as well as in the winter. Trees running up to eight or ten inches in diameter may be treated in this manner. Those above that diameter would best be pulled, because it will be hard to get the bark to grow over the wound completely and

[1]Pruning fruit trees with Special Reference to the Apple. Volck, W. H., California Monthly Bul. VI: 3 and 4, pp. 80-89.

there is always the danger of heart rot starting in upon the stump. The stumps of the trees that are saved should be cut on the slant so that the water will run off well, and then copper tacks should be driven in the wood and the bordeaux paste applied.

In addition to the tacks, Volck advises for the larger wounds, copper screen cut to fit the wood, and held in place by the tacks. The screen acts as a protection from fungous diseases and in addition serves to hold the bordeaux paint more firmly. It should be tacked down closely to the edges. The edges of the cuts may be treated by a mixture of asphaltum (D grade) 8 parts and 2 parts of paraffine. This should be warmed up in a grafting pot and applied with a small brush around the bark and the outer edge of the wood, after the tacks have been driven. It should be understood that there is no paint or whitewash preparation that hastens the healing of the cambium layer over the wounded surface. The most we can do is to give nature a chance to do her best.

If it becomes necessary to pull the trees, the question then arises as to the feasibility of replanting immediately in the same place from which the trees were pulled. This should not be done unless all the large old roots are dug out and fresh top soil thrown in to replace the old soil. In case this careful preparation is made, the young trees should make a good growth provided they are not too shaded by large trees near them and have good cultivation coupled with some fertilizer if needed.

All injured trees that it does not seem necessary to pull, should have the best of cultivation and general care in the future.

What does this experience of last winter teach us about future planting? First, we found out something concerning the comparative

Fig. 2. Wagoners badly injured flanked by Grimes and Yellow Newtowns only slightly damaged if at all.

tenderness of different varieties (see Fig. 2). While we may never again have such a cold spell, still it would be the safest plan not to plant the varieties that have proved most tender unless they are of especially good commercial sorts. Second, good air drainage and water drainage are absolutely necessary for the successful growth of an orchard over a long term of years. Orchards may seemingly thrive for some time on rather wet, flat soils, but as a rule such orchards are shallow rooted and are

Fig. 3. An old devitalized prune orchard almost entirely killed by the cold.

not productive, because often hurt by frosts. When some especially cold weather comes along, they may be entirely killed. Third, careful cultivation, pruning, spraying, etc., are needed to give the tree its best growth and to put it in its most resistant shape for winter. It has been repeatedly observed that trees that have been neglected for some time and are run down in vigor become easy prey to cold winter weather (see Fig. 3). Fourth, trees should not be cultivated too late in the growing

Fig. 4. Looking down the dividing line between two orchards. Trees on the left cultivated late in the season of 1919, those on the right not cultivated after Aug. 1.

season (see Fig. 4). Usually cultivation should stop by the first of August for both young and mature, bearing trees. In some cases, where the crop is especially heavy or where there is no irrigation or where the

fruit is apt to be small, it may be permissible to cultivate for two or three weeks after that time, but even then there is some risk. It is much safer to have the wood well matured before winter sets in. When the cambium layer has been well matured and hardened up for winter, it has been shown by repeated investigations that this cambium is not hurt even by extremely low temperatures. Fifth, fertilizers containing nitrogen should be applied early in the season so that either tree fruits or small fruits may not be kept growing too late in the fall and may have opportunity of hardening up well for winter.

SOME RELATIONS OF GROWTH AND BEARING OF FRUIT TREES TO ORCHARD PRACTICES

By E. M. Harvey and A. E. Murneek

The most highly recommended orchard practices frequently fail to bring about anticipated increases in growth or bearing of fruit trees. Every grower doubtless has experinced at some time such disappointing failures after a trial of the horticultural adviser's best recommendations for forcing the trees to greater effort. A practice which fails in one orchard may give extremely satisfactory results in orchards of another section of the State, or as it sometimes happens, in an adjacent orchard. For example, a heavy application of nitrates to the soil may stimulate an increased bearing of the trees in one orchard, while, next to it, another orchard will entirely fail to give a similar response to the same treatment. Such variations in response of trees are recognized as of frequent occurrence by all persons who have anything to do with our common orchard practices.

These apparent inconsistencies point to the fact that we have neither stopped to analyze the conditions in the orchard, and in the trees themselves, with sufficient care, nor deeply studied these conditions with reference to the true purposes of the various treatments commonly employed. Orchard conditions are usually so extremely complex and our methods of analyzing them so poor, that no single orchard practice can be recommended with much certainty of success in any particular orchard. It is firmly believed, therefore, that future progress in fruit growing requires that we obtain a clear understanding of the place and purpose of each operation carried on in the orchard. But before we may possess such an understanding it is necessary that we have much additional information, which will probably come to us along two general lines. (1) We must learn methods for determining the true conditions prevailing in any orchard with special reference to the actual state of health of the trees themselves. Such methods would enable us to know much more accurately than we can at present what is the cause of the lack of fruitfulness or growth in individual orchards. (2) We need information also concerning the fundamental principles which underlie all the common orchard practices. These principles would teach us what sort of responses to expect from each separate practice or combination of practices under the particular conditions prevailing within the trees.

In regard to the second of these two lines of inquiry, Dr. E. J. Kraus, formerly of this Station, has given us an extremely suggestive theory. The theory concerns some plant-food relationships, which, if found to hold true under more rigid experimental tests, will help wonderfully in controlling the performance of orchards. The theory has already received important experimental confirmation at the hands of Dr. Kraus and Dr. Kraybill. This work was done on the tomato plant and the results published in Bulletin 149 of this Station. While the results of this piece of experimental work lead us to believe that it is quite probable that the plant-food relationships outlined by Dr. Kraus hold true for plants in general and for the tomato and other herbaceous plants in particular, the theory cannot, of course, be taken over bodily and applied to orchards until much rigid experimental testing has been tried on fruit trees. The results of two years' work on fruit trees, carried on by the writers, agree thoroughly with the results of Kraus and Kraybill on tomato. This fact encourages us to outline here Dr. Kraus's idea of the "carbohydrate-nitrogen ratio," as it is called, and to discuss tentatively some of its applications. Dr. Kraus (in Bulletin 149) and Prof. C. I. Lewis (in a small circular and in lectures) have already given rather thorough suggestions regarding the application of the theory to orchard conditions.

Some repetition here, however, will not be out of place since the question is brought up again on account of recent experimental work.

In Bulletin 149 Dr. Kraus aims at the establishment of some of the most fundamental principles of horticultural practice. He begins by calling attention to certain substances which are necessary for plant growth. These he allows to be typified by three substances: water, carbohydrates (e. g. sugars and starch), and nitrogen. There are, of course, many other necessary substances, the lack or shortage of any of which would cause as much disturbance in plant growth as a similar lack of one of the three "typical" substances. But for simplicity of illustration, only water, carbohydrates, and nitrogen are considered. And to simplify still further the idea, we assume that water, too, is plentiful, thus leaving only for present consideration the effects on trees of variations in the amount of carbohydrates and nitrogen. It is believed that the total amount of these two substances is not so important in determining what the performance of a tree will be, as the relative proportions of the two. We are now ready to consider the second important part of the theory; namely, the four classes to which a tree may belong as regards the relative proportions of its contained carbohydrates and nitrogen. These four classes may be briefly described as follows:

Class 1. Carbohydrates are not properly available, but nitrogen may be abundant. Trees of this class will make very little growth and bear no fruit.

Class 2. Carbohydrates are abundant and nitrogen is abundant also. Trees of this class make good growth but bear little or no fruit.

This is the class to which the trees should belong for the first four or five years after planting.

Class 3. Carbohydrates are abundant, but the supply of nitrogen is somewhat restricted. Here the trees make only a small amount of growth, but bear heavily.

This is the class into which all trees should be led after the first few years in the orchard, and here maintained.

Class 4. Carbohydrates are abundant, but the nitrogen supply is very much restricted. In this class the trees make little or no growth and bear little or no fruit.

Most older orchards have a strong tendency to pass into this fourth class from class 3.

If the above classification is once understood and kept in mind, and if it is also remembered that the carbohydrates come from the leaves and the nitrogen from the soil, it will not be difficult to see that each of our common orchard practices must have some tendency to change the relative proportion of the carbohydrates and nitrogen in the tree, either toward the condition of class 4 or in the opposite direction, toward that of class 1. In fact it will be possible to divide orchard practices into two groups with respect to the direction in which they have a tendency to change the trees in the above classification. We may let group 1 be represented by all those practices which tend to change the trees from classes 1 and 2 toward class 3 or 4. This change can be accomplished either by increasing the carbohydrates or by decreasing nitrogen. Orchard practices belonging to this group would be: inter-cropping with non-leguminous plants such as grains, thus decreasing the supply of nitrogen and other soil nutrients; root pruning, which would act in the same manner; and trunk ringing, which would increase the amount of carbohydrates in the top by preventing their flow to the roots. Group 2 would then include those practices which tend to change the trees from class 4 or 3 back toward classes 1 and 2, either by decreasing carbohydrates or by increasing nitrogen. A great many of the orchard practices belong to this group, the various kinds of top pruning, for example,

which reduce the carbohydrates; or use of nitrogenous fertilizers and growing leguminous cover crops, which increase the nitrogen supply; or increased irrigation, which has a tendency in the same direction.

During the first few years after an orchard is set out, the trees should be kept in condition of class 2. Here good growth and no fruiting will take place. But as soon as the trees have remained in class 2 long enough to have acquired a bearing size, the orchard management should be changed to bring them into condition of class 3, in which a moderate growth combined with much fruitfulness will take place. It is, of course, desirable afterwards to maintain the trees in condition of class 3 by a proper balance of cultural treatments belonging to the two groups just mentioned. There is a particularly strong tendency, however, after a few years of active bearing, for the trees to pass over into the condition of class 4 where growth and bearing practically cease. Whenever this situation is approached, only cultural practices of group 2 should be employed (and sometimes one or more of these very severely) in the endeavor to restore the condition of class 3.

It becomes clear that the kind of treatment most desirable for an orchard depends, first of all, on the actual condition of the trees themselves, for any one of the cultural practices is capable either of encouraging or discouraging bearing. For example, top pruning should not be expected to induce bearing when trees are in the condition of class 2.[2]

Fig. 5. Bartlett pear trees. Showing some differences in conditions which can exist in adjacent trees of one variety and age, subjected to approximately the same orchard practices.

Likewise an application of nitrogenous fertilizers would not induce bearing in trees of class 2 or increase it in trees of class 3. But either of these same treatments may be expected to increase bearing if the trees are in condition of class 4. It is worth noting, however, that, though the trees may be in the condition of class 4, where normally they would be assisted to bearing by such treatment, it may happen that the first season

[2] A light summer heading of trees of class 2 will sometimes aid the formation of fruit spurs which lead to earlier bearing. However, another factor called correlation is involved here.

following a severe pruning or heavy application of nitrogenous fertilizers, a vigorous growth but little bearing takes place. In such case the treatment has probably been so severe that the trees are carried back through the condition of class 3 into class 2. But even for this situation, one may expect the conditions rapidly to readjust themselves to those of class 3, providing of course, the treatment previously given is discontinued or greatly diminished in amount.

This theory of Dr. Kraus, outlined above, should be of practical importance in understanding the fundamental principles determining the effects of common orchard practices. If the idea does give a correct understanding of them, it ought to enable every grower to have a much better control over the performance of his trees. In its application it would be necessary to form a careful judgment as to the conditions prevailing in the orchard, and then to proceed with one or more of the orchard practices best suited to correct conditions unfavorable to growth or bearing.

It was mentioned that Dr. Kraus had tested his theory experimentally with favorable results on the tomato plant and that the writers also had made similar tests with similar results on fruit trees. These latter studies have to do with the relation of carbohydrates and nitrogen to various treatments and bearing in apple spurs. The results of this work will probably be reported soon in a bulletin of the Station. A brief statement of the results is given below.

The work consisted of two series of experiments on apple spurs; one series to find the relative proportion of carbohydrates to nitrogen within the spurs that will allow them to set fruit, and the second series like the first with the exception that it considered the question of the formation of fruit buds on the spur. The chief method of controlling the proportion of carbohydrates to nitrogen was by various amounts of defoliation of the spurs. Pruning, being a more common orchard practice, might have been preferred, but obviously one cannot prune a spur and afterwards study the set of fruit or the formation of fruit buds upon it; therefore defoliation, the operation closely corresponding to pruning, was employed.

The spurs studied were of the varieties Grimes, Jonathan, and Wagoner. It was found that defoliation changed the internal relation of carbohydrates and nitrogen sufficiently to throw the condition of the spurs from those of class 3 to approximately those of class 2, a result to be expected from any operation similar to pruning. That the condition of these spurs was actually changed by defoliation from class 3 to class 2 is indicated by two lines of evidence: (1) one that the check (undefoliated) spurs were able to form abundant fruit buds or to set a good crop of fruit, while the defoliated spurs formed few fruit buds and set very little fruit; (2) the other, that defoliation affected the relative proportion of carbohydrates to nitrogen enough so the defoliated spurs contained relatively more nitrogen and less carbohydrates than the check (undefoliated) spurs.

Both the above changes in spurs are in accord with what is to be expected to take place throughout an entire plant like the tomato if its internal conditions are being altered from those of class 3 to class 2. In fruit trees we must not expect the entire plant to respond to treatments so readily or in so great a degree as the herbaceous tomato which Dr. Kraus tested. Woody plants are much more sluggish and their different parts, such as fruit spurs, behave quite independently, as though they were separate individuals. Yet we know that whole trees do respond to orchard practices, and we feel that these measurable changes which we caused to take place in apple spurs are like those which take place to a lesser degree in the tree as a whole.

From the above considerations it becomes clear that other cultural

practices could be similarly tested as to their respective effects on the carbohydrate and nitrogen balance in the tree. Certain investigators have already made some suggestive attempts to interpret on this basis the results of the numerous fertilizer experiments of our agricultural experiment stations. Some of the most diverse and sometimes apparently conflicting results have thus been correlated and tentatively explained.

It must be remembered that complications are sure to arise in directing the various cultural practices along the lines suggested, no matter how well they come to be understood. The effect of extreme variation of environmental factors such as soil, temperature, light, moisture, etc., will always be difficult to interpret and control.

To summarize some of the possible relations existing between a few of the orchard and experimental practices, environmental factors, and the classification as regards the "carbohydrate-nitrogen ratio," we append the following table:

TABLE I. SIGNIFICANCE OF VARIATIONS IN THE RELATIVE SUPPLY OF CARBOHYDRATES AND NITROGEN IN PLANTS

Class I.	Some means of altering the classification of a given plant.	
	I. By relative INCREASE of the ratio.	II. By relative DECREASE of the ratio.
The $\frac{\text{Carbohydrate}}{\text{Nitrogen}}$ ratio relatively *small*. Carbohydrates limiting. Nitrogen abundant. $\frac{C}{N} = V + F.$	A. Directly—Increasing carbohydrates. 1. Favorable aerial conditions (e. g. sunshine and warmth). 2. Injection of carbohydrates into the stem. 3. Ringing trunk. B. Indirectly—Decreasing nitrogen. 1. Natural soil deficiency. 2. Inter-cropping with non-leguminous plants. 3. Decreased irrigation. 4. Root pruning.	A. Directly—Decreasing carbohydrates. 1. Unfavorable aerial conditions (e. g. cloudiness and low temperatures). 2. Attacks of fungi and insects on leaves. 3. Top pruning, through: a. Removal of stored carbohydrates. b. Decrease of leaf surface. 4. Defoliation. B. Indirectly—Increasing nitrogen. 1. Nitrogen fertilizers. a. to soil. b. sprayed upon branches. c. injection of nitrates into the stem. 2. Leguminous cover crops. 3. More available nitrogen supply through: a. clean cultivation. b. increased irrigation.
Class II. Carbohydrates abundant. Nitrogen abundant. $\frac{\mathbf{C}}{\mathbf{N}} = \mathbf{V} + \quad \mathbf{F}.$		
Class III. Carbohydrates abundant. Nitrogen slightly limiting. $\frac{\mathbf{C}}{N} = V + \mathbf{F}.$		
Class IV. The ratio relatively *large*. Carbohydrates abundant. Nitrogen strongly limiting. $\frac{\mathbf{C}}{N} = V + \quad F.$		

In the left-hand column of Table I we have the classification of trees as regards the relative proportion of the contained carbohydrates and nitrogen. Class 1 gives the smallest value of the ratio, carbohydrates, nitrogen and this ratio increases in value through the other classes until it attains the greatest value in class 4. C = carbohydrates; N = nitrogen; V = vegetative growth; F = fruitfulness; use of light face type in these letters signifies that the supply or activity is limited; use of italics signifies that the supply or activity is partly limited, while the use of bold face indicates abundance. In the middle and right-hand columns we give some of the means and conditions that tend to alter the classification of a tree; those named in the middle column tend to change the trees from classes 1 and 2 to classes 3 or 4; and those in the right-hand column tend to cause the opposite effect.

SUMMER PRUNING OF YOUNG APPLE TREES

By E. M. Harvey

INTRODUCTION

Summer pruning of young apple trees is a subject which has received a large amount of attention at the Oregon Experiment Station. This was especially true about five or six years ago, when summer pruning came into popularity and striking results were supposed to accrue through the practice of it. Summer pruning naturally assumed considerable importance in the several experimental pruning studies which were inaugurated during and immediately following that period. In so far as these studies were directed to young apple trees, however, their general purpose was not only to determine the effects of summer pruning, but also to work out some system of pruning, regardless of its kind and degree, which would encourage the most rapid development of the tree and bring it safely through the vegetative and critical, or transitional, period as early as possible. The results of most of this work have long since been published or otherwise made public by the various members of the Station staff.

One of the principal apple-pruning experiments of this kind was carried out by Professor V. R. Gardner on Grimes, Wagoner, Yellow Newtown, and Jonathan. This work was reported in Station Bulletin 139, 1916. Another and similar apple-pruning experiment was soon started that involved two other varieties; namely, Rome and Gano. It was considered that these varieties would justify a separate study on account of a certain difference in bearing habit as compared with the four varieties of the previous experiments. Both the Rome and Gano have a strong tendency to bear, especially their first crops, directly on shoots of the last season, whereas the other varieties bear even their first crops largely upon spurs.

These Rome and Gano experiments were completely outlined by Professor Gardner early in the summer of 1917. The various pruning treatments called for by the outline were carried through by him from the summer of 1917 until the autumn of 1918, when he left the Oregon Station to take up his duties at the Missouri Station. Since that date the writer, with the assistance of Mr. Murneek, has continued the pruning program as planned by Professor Gardner. Owing to the pressure of other work and to the fact that the trees are entering their bearing period, it seemed desirable to bring these experiments to a close this autumn (1920). Hence the present opportunity is taken to make a brief report of the results so far obtained.

THE ORCHARD

About 575 trees each of the two varieties were under experimentation in the orchard, which is described in Professor Gardner's notes as follows: "These trees were set in the spring of 1915. They made a rather poor growth that year. In the spring of 1916 they were given a comparatively heavy pruning, consisting in both thinning out and heading back. During 1916 they made a fair growth. Again this past spring (1917) they were given a rather heavy pruning, consisting of a thinning out and heading back. At the present time they are making a good strong growth, but the trees are about the size they should have been at this season a year ago." In the summer of 1918 he again made a general notation that owing to the hot and dry weather of that season the trees had "not made so good a growth as otherwise would have been expected." It is rather plain, therefore, that this orchard has not been in as good growing condition as is desirable for a young experimental planting, particularly for summer pruning studies. But during the season of 1919 and 1920 these trees have made very good growth throughout, especially in the case of the Ganos in 1919. The very cold weather of last winter (1919-20) probably set the trees back to some extent.

PLAN OF THE EXPERIMENTS

The orchard was divided into four plots, each plot containing about 140 trees of each variety. These plots received the following treatments:

Plot I. Winter heading and winter thinning.
Plot II. Summer heading and summer thinning.
Plot III. Winter heading and summer thinning.
Plot IV. Summer heading and winter thinning.

The pruning throughout this work, as regards its severity, should be classed as heavy to moderate. During the last year not as much as 50 percent of the new growth has been removed at any pruning. The summer pruning was usually done about the first week in July, that is to say, at a time preceding the cessation of growth and the formation of terminals. The winter pruning was done during February or March.

RESULTS

Effects of the pruning treatments on tree growth. From observations of the present season (1920) it appears that the growth of the trees throughout the four plots has been fairly uniform within each variety; that is to say, in walking through the orchard, no striking differences between the plots are evident. Though the Ganos have made a greater growth than the Romes, this is a variety characteristic and has little or nothing to do with the pruning treatments.

On closer observation it can be noted that both varieties in the plot receiving only winter pruning have made a little more growth than any of the others, and that they appear to be in a little better condition, generally. This apparent better condition of the winter-headed and winter-thinned trees is shared to only a slightly lesser degree by those receiving a summer heading, combined with a winter thinning. It is, therefore, partly to be accounted for by the fact that summer thinning has left the trees of the other plots with more open tops. Plates I and II show representative Rome and Gano trees of the various pruning treatments.

TABLE II. RELATION OF PRUNING TO GROWTH OF YOUNG APPLE TREES, AUTUMN, 1920

(Based on the average of 70 trees of each variety and treatment.)

Variety.	ROME.						GANO.					
Pruning.	Diameter of trunks.		Spread of tops.		Height of tops.		Diameter of trunks.		Spread of tops.		Height of tops.	
Treatment.	Diameter.	Winter pruning only.	Spread.	Winter pruning only.	Height.	Winter pruning only.	Diameter.	Winter pruning only.	Spread.	Winter pruning only.	Height.	Winter pruning only.
	in.	%	*in.*	%	*in.*	%	*in.*	%	*in.*	%	*in.*	%
Winter heading and winter thinning...	1.74	.....	54	.....	77	.....	1.82	.....	69	.....	80	.....
Summer heading and summer thinning.....	1.66	95.4	49	90.7	75	97.4	1.72	95.0	63	91.3	78	97.5
Summer heading and winter thinning.....	1.72	98.7	48	88.9	72	93.6	1.74	95.6	58	84.1	71	88.7
Winter heading and summer thinning.	1.73	99.4	44	81.7	71	92.2	1.73	95.1	54	78.3	70	87.5

Summer thinning appears to have had no beneficial effects on growth. At the end of the 1917 growing season the shoots of the summer-thinned trees had made a little more growth than the winter-pruned only, and the shoots were perhaps a little stouter. The total accumulative effect today, however, is not in that direction, as shown by measurements made this autumn of trunk diameters and height and spread of the trees. It will be seen from Table II that the height and spread of summer-pruned trees are less than those receiving winter pruning only, but greater than the other two pruning combinations. But that the summer-thinned trees were in the poorest condition of all as to growth is indicated by the trunk diameter measurements, which are considered to be better indices of tree growth than height or spread. Except in cases where the soil nutrients themselves are deficient (and such a situation would be unusual in a young orchard), one should expect a summer thinning to decrease the elaborated foods of the tree more and induce less renewed twig growth than a summer heading which removes the same amount of twig and leaf area. If an equal area of leaves were removed, say in June, by summer thinning and summer heading, a larger percentage of this area, in case of summer thinning, would have been engaged in manufacturing and storing foods for the general supply of the tree. The pruning stimulus is also so extremely localized that a shoot is much more likely to be induced to renewed growth by a heading than by having its neighbor cut away.

Summer heading in these experiments has caused very little secondary shoot growth to take place. After the first summer heading in 1917 the resulting shoot growths were short, thick, and spur-like, ½ to 6 inches long. In 1918, likewise there was little renewed growth, and in 1919, practically none at all. But this season (1920) a relatively good growth has taken place, giving secondary shoots 4 to 12 inches long.

As to the relative effects of summer and winter pruning and combinations of them, it would seem for many reasons that winter pruning offers a lesser set back to growth than any type of summer pruning. Consequently when winter heading is combined with winter thinning, the greatest growth is allowed to take place. But if this assumption is accepted that winter pruning is less detrimental to growth than summer pruning, one should expect the combination of summer heading with summer thinning to give the least growth of all. Table II shows that it was not entirely the case in our experiments. The trees which received heading and thinning in the summer probably made relatively more growth than would be expected, for the practical reason that when the operations of heading and thinning are separated and performed at different seasons of the year, there is a strong tendency to make the total amount cut away by the two separate operations greater than when both are performed at once, whether it be summer or winter. Great care is thus necessary to avoid too severe cutting, if both summer and winter pruning is practiced on the same tree. No advantage, in fact, so far as growth in young trees is concerned, should be expected to accrue from a summer pruning in any combination. Judicious summer pruning probably has a place in the training of young trees during their first and second year in the orchard, as pointed out recently by Tufts.[3]

Effects of the pruning treatments on fruit-spur formation and bearing. General observations, in this orchard of Romes and Ganos, do not show that any of the treatments calling for summer pruning have been of aid to the production of fruit spurs. This fact is of considerable interest, since it is for such purpose that summer pruning, especially early summer heading, is usually recommended. In connection with the apparent fact of the failure of summer pruning to stimulate spur forma-

[3]Tufts, W. P., Bul. No. 313, Cal. Agr. Exp. Sta. 1919.

tion, the bearing habit of the varieties Rome and Gano should be taken into consideration. Both these varieties have a tendency not to form many fruit spurs and to bear their first crops on long, slender shoots of the preceding season growth. Evidently this habit is not broken up by summer pruning. Summer pruning coupled with such a bearing habit tends to reduce, if anything, the amount of fruit-bearing wood. The

TABLE III. RELATION OF PRUNING TO BEARING OF YOUNG APPLE TREES

(Based on averages of 70 trees of each variety and treatment.)

Variety.	ROME.				GANO.			
Treatment.	Average number of fruit per tree.	Per cent of winter pruned only.	Average weight of fruit per tree.	Per cent of winter pruned only.	Average number of fruit per tree.	Per cent of winter pruned only	Average weight of fruit per tree.	Per cent of winter pruned only.
		%	*oz.*	%		%	*oz.*	%
Winter headed and winter thinned	2.61	.....	15	.....	5.77	.....	28	.....
Summer headed and summer thinned	2.54	97	13	90	2.25	39	11	38
Summer headed and winter thinned	0.76	29	4	27	1.13	20	5	20
Winter headed and summer thinned	0.36	14	2	13	0.57	10	3	10

crop records as presented in Table III seem to substantiate this statement. The extremely low temperatures of last winter possibly affected these crop results, though it is not known to what extent. As they stand, they show that the trees which received winter pruning only bore more fruit than those of other treatments having some summer pruning. The conclusion is drawn that from the standpoint of early bearing of such apple varieties as Rome and Gano, summer pruning offers no advantages over winter pruning.

THE PRESENT STATUS OF THE SUMMER PRUNING QUESTION

Horticulturists are not paying so much attention to the summer pruning question now as they did a few years ago. Neither are they recommending the practice to any great extent. None of the recent bulletins on the subject of pruning have had much to say in favor of summer pruning as a regular orchard procedure. This change of attitude is due to several circumstances. Perhaps the principal one is that many of the advantages which were supposed to result from summer pruning did not materialize when careful studies of the question were made. It is still granted that under some conditions summer pruning is of great value, but there are in the orchard so many different factors conditioning its favorable results that the practice is not to be recommended except for very special purposes. Summer pruning is more weakening to a tree, moreover, than winter pruning of the same amount and kind. This is especially noticeable when summer pruning is done late in the season as in July or August. For this reason such pruning is recommended to be done in June, or sometimes in May, before growth has ceased.

Some of the special functions which judicious summer pruning is still believed to possess may be illustrated as follows: Trees having a tendency to grow too nearly upright can sometimes be thrown into a wider branching form by means of summer heading; when trees have

reached the bearing age a light summer heading may also stimulate an earlier and greater production of fruit spurs; or, as Tufts of California has pointed out, in the training of very young vigorously growing trees, summer thinning can be used advantageously for directing a rapid building of scaffold branches. It would be well always to keep in mind that no summer pruning for any purpose should be performed unless the trees are in a good growing condition.

At the present time the conclusion seems warranted that summer pruning should be avoided except for special purposes and then only when the orchard conditions, and the responses of the varieties under consideration are well known. These characteristic varietal responses should always receive close attention previous to any kind of pruning operation, particularly is this true when summer pruning is under consideration.

SUMMARY

(1) This article constitutes a report on a series of pruning experiments which were started by Professor Gardner in 1917 and continued by other members of the staff since the autumn of 1918.

(2) These experiments were planned for a study of the effects of various types of summer pruning on the growth and fruit-spur formation in young apple trees. The study involved about 1100 trees of the varieties Rome and Gano.

(3) All types of summer pruning have allowed less tree growth than winter pruning only.

(4) Fruit-spur formation apparently has not been stimulated by summer pruning as compared with the winter pruning only. The failure to respond in this respect to summer pruning may be attributed to the characteristic bearing habits of the Rome and Gano.

(5) Likewise the amount of fruit harvested this season was less from summer-pruned trees than from those which had received winter pruning only.

(6) Nothing in the results of this series of experiments would justify the recommendation of summer pruning for young trees of such varieties as Rome and Gano.

(7) The results of these experiments, when compared with those reported by other investigators working with different varieties, emphasize the necessity of regulating pruning practices in accordance with the natural growing habits of the varieties under consideration.

(8) As a general pruning practice in young orchards of any variety it would seem advisable to do summer pruning with great caution, even though it is recognized that under special circumstances light early summer pruning may be very beneficial.

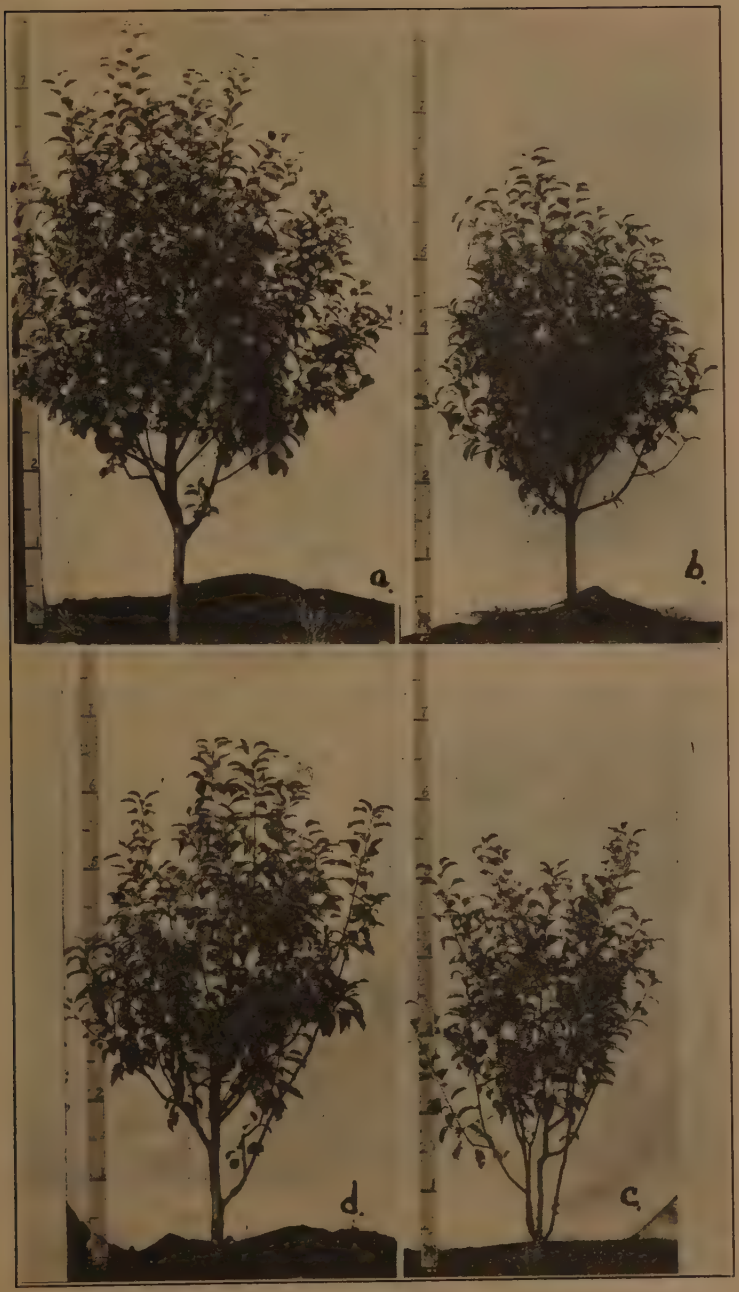

PLATE I

Rome: (a) Winter headed and winter thinned; (b) summer headed and winter thinned; (c) winter headed and summer thinned; (d) summer headed and summer thinned.

PLATE II

Gano: (a) Winter headed and winter thinned; (b) winter headed and summer thinned; (c) summer headed and summer thinned; (d) summer headed and winter thinned.

THE STORAGE OF BOSC PEARS

By A. E. Murneek

In respect to general appearance and quality the Bosc is a premier pear. As one of the few really good large dessert pears, it tops the list. Its season, however, is rather early; it is often off the market by the middle of November. Due to the showiness and quality of the fruit, there has been a persistent tendency to make the Bosc an early winter pear, to keep it for the lucrative Christmas trade. The many different types of storages used for this purpose, however, have given very poor results, creating general discouragement in attempting to lengthen the season of this variety.

Aware of this situation, the Oregon Agricultural Experiment Station has for the past three seasons endeavored to find a storage that will permit the keeping of Bosc till mid-winter and yet not materially interfere with the quality of the fruit. These investigations have been conducted in the Rogue River Valley, where the largest acreage of Bosc is to be found and where this variety grows to perfection.

PRELIMINARY INVESTIGATIONS

The work was begun in 1917. Fruit from two typical orchards, one with rather heavy soil and irrigated, the other with medium heavy soil, non-irrigated, was used for this preliminary study. The following types of storages were employed in 1917:

Storages Used in 1917.

(1) Common storage—Temp., 45 to 70° F.; hum., 40 to 70%.
(2) Common humid storage—Temp., 45 to 70° F.; ave. hum., 90%.
(3) Car temperature storage—Temp., 50 to 62° F.; hum. 60 to 75%.
(4) Cold dry storage—Temp., 36 to 38° F.; hum., 60 to 75%.
(5) Cold humid storage—Ave. temp., 32° F.; hum., 80 to 85%.
(6) "Delay" storage[4], followed by cold dry storage.

During the first year great difficulty was experienced in obtaining Bosc pears of good quality when held under practically any kind of storage condition that materially retarded ripening of the fruit. Specimens that were kept in cold storage from the very beginning, when removed were worthless for commercial purposes, the surface being soft or decayed, while the interior was still green. Similar poor results were obtained when Bosc were kept at a temperature of 50 to 62° F. While a few specimens ripened well enough under these conditions, most of the fruit was mellow on the outside, the interior remaining hard and unpalatable.

No real reason for this behavior could be deduced from the first year's results. It was thought, however, that possibly low temperatures so retarded the normal ripening processes of the fruit that it remained green in the interior while the outer part was undergoing a physical breakdown. Chemical analysis showed that there was considerably less sugar present in Bosc pears ripened in cold storage than when kept at room temperature.

These results pointed out that possibly a partial ripening for a week or longer, or a delay in storage, would facilitate an initial change, which would then permit the keeping of this variety at lower temperatures or even in cold storage. With this view in mind an elaborate series of storage tests was inaugurated during the season of 1918.

INVESTIGATIONS IN 1918

Pears from four orchards, exhibiting characteristic differences in soil, moisture content and age of trees, were used for this investigation. Only average typical fruit from average trees was considered. They were

[4]An ordinary packing room was used as delay storage. The fruit was kept for 4 to 5 days in this room, then transferred to cold dry storage.

packed at intervals of seven days, beginning a number of days in advance of the general picking time in the respective orchards and extending a week or ten days beyond it.

Storages Used in 1918.

(1) Cold storage—Temp., 35 to 36° F.; ave. hum., 82%.
(2) Room temperature storage—Ave. temp., 73° F.; ave. hum., 47%.
(3) Common storage—Ave. temp., 65° F.; ave. hum., 70%.
(4) Car temperature storage—Ave. temp., 53° F.; ave. hum., 73%.
(5) Delay 7 days, then cold storage.
(6) Delay 7 days, then car temperature.
(7) Delay 7 days, then car temperature for 12 to 15 days, then cold storage.
(8) Delay 7 days, then car temperature for 12 to 15 days, then room temperature.
(9) Delay 14 days, then cold storage.
(10) Delay 14 days, then car temperature.
(11) Delay 14 days, then car temperature for 12 to 15 days, then cold storage.
(12) Delay 14 days, then car temperature for 12 to 15 days, then room temperature.

A side room of a packing house was used for "delaying." The temperature of this room fluctuated around 70° F. Humidity, approximately 50%.

It is to be noted that in choosing the various types of storages emphasis has been laid upon "delaying" the fruit before storing. Thus

TABLE IV. INFLUENCE OF TYPE OF STORAGE AND TIME OF PICKING UPON KEEPING QUALITY OF BOSC PEARS

Summary of all Orchards—1918.

Kind of storage.	Early picked fruit.		Late picked fruit.	
	Number of days in storage.		Number of days in storage.	
	Prime eating.	Decayed.	Prime eating.	Decayed.
(1) Cold storage	.....	186	.....	181
(2) Room temperature storage	20	50	34	46
(3) Common storage	34	60	33	56
(4) Car temperature storage	53	61	31	73
(5) Delay seven days then cold storage	.....	186	183	196
(6) Delay seven days, then car temperature	31	47	35	69
(7) Delay seven days, then car temperature for 12–15 days, then cold storage	100	145	92	138
(8) Delay seven days, then car temperature for 12–15 days, then room temperature	28	47	34	46
(9) Delay fourteen days, then cold storage	152	182	135	181
(10) Delay fourteen days, then car temperature	36	62	36	58
(11) Delay fourteen days, then car temperature for 12–15 days, then cold storage	73	138	74	129
(12) Delay fourteen days, then car temperature for 12–15 days, then room temperature	37	53	34	50

of the twelve different kinds of storage used, eight were in connection with a "delay" of either a week or two weeks' duration.

Every five days the fruit was examined and judged in respect to maturity, and later its eating quality was given careful consideration. When the majority of pears in each lot were ripe, they were examined for color and tested for texture and eating quality. A lot was considered in "prime eating" condition when more than half of the specimens were of the characteristic golden color and were juicy and of the highest possible flavor. When more than 50 percent of fruit in a lot had decayed the whole sample was discarded. In order to show a difference in respect to time of keeping of early- and late-picked fruit, the results are given in separate columns.

From Table IV it is seen that fruit kept the longest in strictly cold storage (1) or when delayed for fourteen days and then put in cold storage (9). This is but natural, for the length of life of a fruit is dependent primarily upon temperature. In all cases where the above storage was employed the quality, however, was invariably poor. Many specimens decayed even before they attained full maturity. Thus our previous year's results were corroborated, and it was emphasized once more that cold storage is of no value for preserving Bosc.

Lots that were delayed for 7 and 14 days respectively, then put in car temperature for 12 to 15 days (usually 14 days), and finally placed in cold storage (7) and (11), kept next longest. Those delayed for 7 days were in "prime eating" condition in about 3 months and had decayed in approximately 4½ months. Considering the length of storage they were of fairly good quality, though a few specimens, particularly those picked early, were of rather flat taste and leathery in texture.

A surprising improvement in eating quality was obtained when a delay of 14 days was afforded in place of 7 days. The fruit was quite mature, juicy, and of good flavor. Under such conditions they were in state of "prime eating" in 2½ to 3 months, and decayed only slightly earlier than those delayed for 7 days, or in about 4 to 5 months.

In respect to length of keeping all lots in the remaining storage exhibited quite similar results. The fruit ripened in about one month and decayed in 1½ to 2 months.

The amount of humidity had a most telling effect upon the texture of the fruit. Bosc pears that were kept for any length of time in a storage with less than 70% humidity shriveled quite markedly, particularly around the stem end. Thus all specimens when kept at room temperature (average humidity 47%) were very dry and more or less shriveled. So, too, delaying (approximate humidity 50%) of 7 days resulted in slight shriveling around the stem, while a delay of 14 days produced a marked drying of the stem end, which persisted till the time of closing of the experiment. The quality of the fruit diminished because of this loss of moisture in exact proportion to the amount of such loss, as judged by the extent of drying. The lowering in moisture content of the fruit was undoubtedly due to excessive transpiration and may have caused a partial check in the normal physiological changes of the ripening fruit—hydrolysis of starches into sugars, etc. Thus it was clearly evident that for the proper ripening and best quality of Bosc pears a fairly high degree of humidity must be maintained in the storage room. This is particularly true of fruit picked very early in the season. Such fruit is subject to loss of moisture because of its more immature condition.

As a result of our second year's work, some interesting and valuable facts were brought to the front. "Delaying" was found to be of much value in connection with the storing of Bosc. A delay of two weeks in all cases gave better results as compared with a delay of one week. The question was raised, however, as to whether fourteen days is the limit that may be successfully employed in this respect. As considerable shriveling

developed after a delay of two weeks, accompanied by a marked lowering in eating quality, it was clearly evident that the storage used for delaying must have a fairly high percent of humidity; at least it should be above 50%. But since the rate of ripening evidently depended not only upon temperature, but also upon relative humidity, naturally, then, a marked increase in humidity of the storage would tend to shorten the time of delay. Moreover, it was of interest to learn whether a car temperature lower than that obtained during our second season's work would not be of material benefit in keeping some of the delayed lots, as it would permit the shortening of the following cold storage period.

To answer some of these questions, a new series of storage tests was conducted in 1919.

THIRD SEASON'S WORK

As during the previous season, pears were obtained from four representative orchards, exhibiting characteristic differences in soil and moisture contents. Altogether five pickings were made, covering the whole harvesting season.

Storages Used in 1919.

(1) Common storage—Ave. temp., 60° F.; ave. hum., 70%.

(2) Car temperature storage—Ave. temp., 42° F.; ave. hum. 73%.

(3) Delay 14 days, then car temperature for 12 to 15 days, then cold storage.

(4) Delay 14 days, then car temperature for 12 to 15 days, then cold storage (fan).

(5) Delay 20 days, then cold storage (fan).

(6) Delay 20 days, then cold storage (fan) for 60 days, then car temperature.

All fruit was delayed in common storage, which, as seen above, registered an average humidity of 70%, as against a humidity of only 50% in the delay room used during the preceding season. The car temperature storage in 1919 averaged 42° F., or 11° lower than in 1918. A fluctuating temperature prevailed in the cold storage rooms, averaging 32° to 40° F., with a humidity of 75% to 87%. As a large number of the pears during 1918 broke down in cold storage because of scald, and as it has been recently found that scald on apples is markedly diminished by circulation of air, it was thought of value to test what effect air movement will have upon the condition of fruit in this storage. Hence three lots were kept in cold storage with an electric fan running most of the time.

While the pears were in delay storage it became evident very early that a delay of twenty days when followed by car temperature would ripen the fruit too far. All such lots as were marked for a twenty-day delay were therefore put directly into cold storage instead of transferring them through car temperature to cold storage.

All lots were checked up at intervals of one week, the same criterion being employed for judging the general state of maturity as during the preceding season.

Table V shows that pears that were delayed for 14 days, then placed in car temperature for 12 to 15 days, and finally kept in cold storage, held up the longest. They ripened in 2 to 3 months and were decayed in 3 to 4 months. On the average, fruit of these lots was of very good texture and eating quality, and excellent in general appearance. The pears did not show any considerable shriveling. This was undoubtedly due to the comparatively high moisture content of the delay storage. Hardly any change in length of keeping time was noted when a fan was used in connection

with cold storage. In this case the fruit was practically of the same quality. No apparent difference in amount of scald was found as a result of this extra circulation of air.

TABLE V. INFLUENCE OF TYPES OF STORAGE AND TIME OF PICKING UPON KEEPING QUALITY OF BOSC PEARS

Summary of all orchards—1919.

Kind of storage.	Early picked fruit.		Late picked fruit.	
	Number of days in storage.		Number of days in storage.	
	Prime eating.	Decayed.	Prime eating.	Decayed.
(1) Common storage	43	54	27	41
(2) Car temperature storage	73	85	72	81
(3) Delay fourteen days, then car temperature for 12–15 days, then cold storage	97	119	71	95
(4) Delay fourteen days, then car temperature for 12 to 15 days, then cold storage (fan)	105	118(?)	62	97
(5) Delay twenty days, then cold storage (fan)	93	111	55	88
(6) Delay twenty days, then cold storage 60 days, then cool storage (40 to 50° F.)	90	106	60	80

When Bosc pears were delayed for 20 days and then put in cold storage, either with a fan or without, they were ready to eat in 2 to 3 months and decayed in about 3 to 3½ months. It is clearly seen that a delay of 20 days in this case was much too long, particularly so with the late-picked and more mature fruit. Though the quality of pears in these lots was very good, a few specimens had broken down around the core, while the outer part of the flesh was in a good condition.

Fig. 6. The Bosc is a premier pear.

Marked differences may be noted between length of keeping of car temperature lots in 1919 as compared with lots in the same type of storage in 1918. This may be safely ascribed to a difference of 11° in temperature of the storage in 1919 as compared with that of the preceding season.

Lots kept in common storage only were used as checks.

SUMMARY

The above storage investigations conducted during the past three seasons have brought out the following facts:

(1) Time of picking does not very materially influence the storage quality of Bosc pears, excepting that fruit picked very early in the season must be permitted a delay or partial ripening under more humid conditions and for a longer period than when picked later in the season.

(2) With the proper precautions, Bosc pears may be kept successfully for three months, or possibly longer—at least for the Christmas trade. Based on our present information, the following storage procedure appears to be the best: Delay for 10 to 15 days, then car temperature storage for 12 to 15 days, then cold storage.

(3) To prevent shriveling of "delayed" fruit, a humidity of 60% to 70% must be maintained in the delay room. The higher the humidity the less time would be required for a "delay."

(4) Both relatively high temperature with low humidity and low temperature with high humidity are harmful to the proper ripening of Bosc.

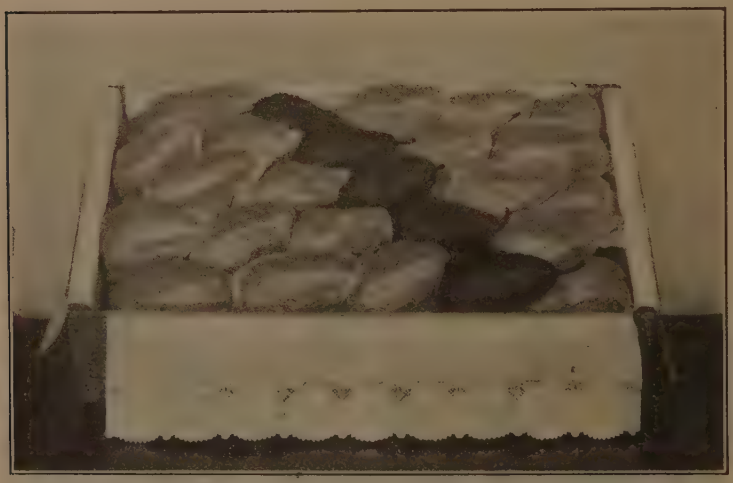

Fig. 7. Bosc pears are commonly packed in fancy half-boxes.

VEGETABLE GREENHOUSE CROPS IN RELATION TO THE USE OF THE GREENHOUSE FOR ONE SEASON

By A. G. B. Bouquet

While the acreage of ground covered by glass used for forcing vegetables in Oregon is not extensive compared with many other states, yet the business is steadily increasing and will continue to do so in accordance with the growth of Northwestern cities and the general development of the West. Construction of greenhouses which otherwise would have been made in the last few years has been considerably handicapped by the prohibitive prices of glass and other materials. When these reach a level more nearly approaching normal there will be a marked increase in building. There are many communities which could well support a greenhouse range to furnish fresh vegetables out of season and to produce young plants for field transplanting.

Methods of using a vegetable greenhouse that are employed by those having ranges may be divided into two classes; first, the use of the space for one single crop during a portion of the year, the greenhouse area being unproductive the balance of the twelve months; second, the use of the ground for two or more vegetables, in which case the greenhouse is productive during almost the entire year.

With considerable investment in a range of any size, it is manifestly desirable that there be no unproductive areas in the greenhouse at any time during the year, but this condition nevertheless is found to exist in several instances.

FACTORS INVOLVED IN THE PRODUCTION OF A SINGLE CROP IN SEASON

In some cases only one vegetable is grown in a greenhouse in twelve months. This may be either cucumbers or tomatoes. Where cucumbers are produced, the methods hitherto used by some growers have been to start the plants in November, and have the vines bearing in February; the harvesting continuing until July. From that time on to November again the house will be unproductive, most of the grower's time being occupied in removing the old vines, clearing up the greenhouse, taking out old soil and bringing in new. In some cases the skillful methods of cucumber growing and the large yields obtained have brought a high return for a comparatively small greenhouse area. For example, two greenhouses in the State, each 35 x 100, and connected to each other, have yielded annually between 3200 and 3700 dozen marketable cucumbers. In the case of this range, no other crop was produced, the attention of the operators being entirely concentrated on one crop.

Again, in some instances, the tomato is the only vegetable produced during the entire twelve months. An example is cited of one greenhouse of the ridge and furrow type measuring 6600 square feet in which tomatoes alone are grown, returning annually approximately $2000 to $2500. In this case, also, the attention of the grower is entirely devoted to tomato production.

In the first example there is no desire on the part of the owners to grow any other vegetable, cucumbers being the specialty. In the second example those operating the tomato house have been growing no further crops, presumably because of the difficulty of finding a satisfactory market for any certain vegetable that might be forced.

FACTORS INVOLVED IN CONTINUOUS CROPPING OF VEGETABLE GREENHOUSE

As opposed to these instances there are other greenhouse ranges where the attempt is made to keep the ground constantly producing dur-

ing the entire year. In this connection it is important to observe the present condition of the lettuce market.

DECLINE IN MARKET FOR LEAF LETTUCE

Ten years ago or thereabouts there was a strong demand for loose leaf lettuce by the larger markets of the State, notably Portland. Lettuce, therefore, was grown by those operating vegetable greenhouses. At that time labor was comparatively cheap and there was a fair margin in growing lettuce during the fall, winter, and early spring months. Since that time, however, there has been a gradual decline in the demand for leaf lettuce, due to the importation of solid head lettuce from California, from which state shipments are regularly received from October on to April or up to the time that the first outdoor Oregon lettuce is available. The consuming public have almost entirely given their preference to solid head lettuce in contrast to the leaf type.

DIFFICULTIES EXPERIENCED IN GROWING HEAD LETTUCE UNDER GLASS

Head lettuce has never been grown in Oregon greenhouses with success sufficient so that it would be entirely free from tip burn. Growers who have successfully produced leaf lettuce have failed to grow head lettuce successfully, mainly because of tip burn, the plants being most susceptible when nearing the stage of solidity.

The basis of marketing lettuce is largely on solidity. The southern lettuce grown outside in the cool season of the year is usually very solid and hence finds a better demand than the head lettuce grown under glass.

Again, the type of head lettuce successfully forced in other parts of the country, namely, May King, Hittinger's Forcing, etc., of the butterhead, smooth-leaf type, does not find a ready sale in these parts as compared with the darker green Iceberg and New York as grown outdoors in the South. Southern lettuce can be grown more cheaply also, and put on the markets here at a cost that will make it difficult for greenhouse head lettuce to be grown at a profit.

SUBSTITUTE CROPS FOR LEAF LETTUCE DURING FALL AND WINTER

The Experiment Station, having observed the conditions previously described, has sought to ascertain what vegetable might be grown after the main crop of tomatoes or cucumbers had been finally harvested or after the removal of the plants. The following crops have been grown:

Spinach. This vegetable makes a rapid growth during the fall, and in greenhouses without any heat two crops have been grown between August 25 and November 15. The first sowing of spinach seed has usually been made during the third week in August, following the removal of tomato plants. This crop is ready for cutting in five weeks from time of seeding. Harvesting takes place about September 20. Second seeding, immediately made, was large enough for cutting November 10 to 15, thus assuring two crops in ninety days. The second crop takes 12 to 14 days longer for a suitable size than the first crop, due to the decline of light and heat. The greatest yields of spinach have been obtained by having the rows 6 to 8 inches apart, the yields averaging ½ to ¾ pound per square foot. Prices prevailing have been 10c to 12½c per pound, and the demand has been good.

This vegetable is considered to be a suitable crop following tomatoes or cucumbers for early fall and through the winter. In the greenhouse cited above, containing 5640 square feet of actual cropping space, the owner could have grown two crops of spinach before December 1, which would have produced, on a conservative estimate, not less than 5000 to 6000 pounds of spinach at a price which is estimated at 10c a pound.

Cauliflower. This vegetable can be successfully grown with very little if any heat during the fall and winter months. The soil may be cropped in such a manner that spinach may be grown between cauliflower plants, the spinach being harvested before it is large enough to interfere with the growth of the cauliflower. The latter crop should be seeded about three and one-half months before harvesting. Erfurt, Snowball, and Gilt Edge are varieties which have been grown in the Station greenhouses. Good heads have been produced from all three kinds, but the character of the crop grown is rather a question of a good strain of seed and well-fertilized soil. If the seed is sown in early September, heads should be produced from Thanksgiving on to Christmas. If cauliflower is to follow tomatoes and cucumbers directly, the plants should be started so as to be set in the beds in September. Plants are usually grown 24" x 24".

Under glass fine white heads are produced, which readily sell for 25c or 30c apiece.

Radishes. Radishes are rapid growing under cool conditions, and can be depended on to produce a crop in from 30 to 50 days, according to the time of year and the variety grown. Rows are usually spaced six inches apart for such varieties as White Icicle and Scarlet Globe White-tipped, and they may be even closer for the smaller-topped varieties of radish. It is customary to include from 6 to 10 roots in a single bunch, depending on the variety. This vegetable makes a profitable filler between crops when there is but a short time intervening.

Fall Cucumbers. If the plants of this vegetable are started at such a time that they are large enough to be set in the greenhouse beds in late August or early September the result will be that the cucumber plants will make a good fall growth and produce well until the time when the weather and light conditions become unfavorable. The season for fall cucumbers will usually extend to nearly Christmas time. Following the fall frosts of early October there is a brisk demand for this vegetable grown under glass, prices usually prevailing at $1 to $1.75 per doz. More heat is, of course, required for this vegetable than for any other crop offered as a substitute for lettuce.

Fall Tomatoes. Cucumbers will make a comparatively greater growth during the somewhat unfavorable conditions of the fall and winter than will tomatoes, and while it is possible to grow a crop of the latter during September, October, November, and December, yet there are difficulties attending, and the tomato is not recommended by the Station to be grown extensively as a fall vegetable. It is true, however, that the plants will ripen fruit through November and December, often with but little artificial heat; but the yield is light as compared with the spring and summer crop.

SUMMARY

(1) Several greenhouses in the State are idle during a portion of the growing season due to the decline of the market for leaf lettuce.

(2) The Experiment Station has conducted trials with several different vegetables to ascertain their adaptability as forcing crops during the season of the year extending from September to March.

(3) Spinach, cauliflower, radishes, cucumbers, and tomatoes can be grown as profitable substitute crops for leaf lettuce, the first three vegetables requiring but little artificial heat for a satisfactory crop.

(4) Cucumbers are preferable to tomatoes as a fall crop, making a more extensive growth and producing more heavily under the declining light conditions of the fall.

(5) It is clear that there is no good reason why all vegetable greenhouses should not be intensively cropped during the entire growing season.

FACTORS AFFECTING PRODUCTION AND MARKETING OF BROCCOLI

By A. G. B. Bouquet

The broccoli or winter cauliflower crop is an important one in Western Oregon, being included among those vegetables which are grown in the State extensively enough to be shipped in car-loads to eastern markets. Douglas county produces annually from 75 to 100 carloads, while Clackamas and Multnomah counties also load out a few cars each year. The Coast counties, especially Coos county, are becoming more interested in broccoli, and the crop is now planted for cannery purposes; in the future, no doubt, it will be shipped in a fresh state to eastern points.

In view of the commercial importance of broccoli, therefore, the Experiment Station has taken steps to investigate two vital problems connected with the production and harvesting of the crop. These problems are (1) the relative commercial value of the seed strains of the vegetable now being grown, and (2) the factors affecting the shrinkage and condition of broccoli heads after they have been severed from the plant.

RELATIVE VALUE OF SEED STRAINS

In the production of any vegetable, the uniformity of the crop in the field, its trueness to type, market characters of value, and yield, are determined to a very great extent by the strain of seed used, consistent with reasonably good methods of field culture. At the present time there is a wide difference between the values of individual broccoli fields because of the different seed strains now being grown. As a matter of fact, serious losses have been experienced by some growers due to deteriorated seed strains producing crops of little value. One grower recently suffered a loss of over $2000 through the failure of the plants to make marketable heads.

At the present time there are as many as twelve different strains of broccoli to be found in the production area. This condition is brought about by the fact that in many cases growers purchase seed individually instead of through an organization, hence increase the number of different sources of seed, each strain of which varies in quality. Added to this also is the fact that some growers are saving their own seed, and in doing so are bound to differ, one from the other, in the selection of type plants as well as in the quality of the seed produced.

Where seed plants are being grown, there is likely to be crossing, during the flowering period, with such other related plants as cabbage, kale, turnip, and mustard. As a matter of fact, these crosses, which have perhaps taken place unknown to the grower, have been responsible for several unprofitable broccoli fields. It is necessary for those who are growing their own seed to be careful not only in the selection of the proper type of plant, but also to see that these plants, when in the flowering stage, are properly covered with cheese-cloth in case there is any possibility of crosses with other crucifers in the vicinity.

Deteriorated types of broccoli are to be found to greater or less extent in most broccoli fields in such forms as leafy and ricey heads, plants which are almost abortive or have no white head (inflorescence or curd). Plants which have been cropped with other members of the cabbage family are also found in varying numbers.

Some **undesirable types** of broccoli that are prevalent include the following:

(1) **Kale type.** Plant tall and spreading; long stem; leaves long, narrow, and lobed; center of plant loosely open; head, if any is produced, small, of inferior type, and unfit for shipment.

(2) **Cabbage type.** Plant showing cabbage cross; stem medium long; leaves light green, prominently veined; center of plant has form of cabbage head, but breaking away tight-head leaves usually discloses broccoli curd compact, white color, but quality inferior, ordinarily being "ricey."

(3) **Open, loose type.** Plant large, tall, vigorous; center of plant open and loose, head small and unprotected by jacket leaves.

A desirable type of broccoli plant and head is summarized as follows: Plant large, vigorous, 36 inches high, branching close to ground, stem short, thereby permitting covering to prevent freezing, plant leaves three times as long as wide, averaging 27 to 35 inches by 9 to 10 inches, center, midrib prominently white; color of leaves, upper side dark bluish green, under side slightly lighter shade; head leaves or jacket showing tendency

Fig. 8. True type of broccoli, showing typical plant characters, veining of leaves, and solid white head, in proper condition for marketing.

to curl over head, protecting it; curd compact, showing no divisions; color clear white, measuring 6 to 8 inches horizontal diameter, vertical section rounded and deep; head showing no evidence of leafiness or riciness.

The above description of the desirable type for selection shows the necessity of observing such important characters as vigor of plant; dark green leaves with prominent midrib; low growing habit, so that in case of severe weather the stem, which is most susceptible to injury by frost, may be covered with dirt by ridging between the rows; self protection of curd by jacket leaves; and finally a medium large head of good color and quality.

In order to determine the relative merit of the various strains being grown, these were grouped for observation, each strain receiving as far as possible identical field treatment. These tests are located in various fields in important districts where the crop is grown.

The values of the strains are as indicated by those heads of shipping value, those showing crossed types, plants with small unmarketable heads, etc., as tabulated in Table VI.

This table shows the records of only a few of the strains tested, the others varying in their value from Nos. 2 and 3 to No. 1. From the above, it is to be noted that strains 2, 3, and 4 show marked superiority, producing profitable yields and making desirable fields from which to save seed plants.

Field trials of the spring of 1920 were considerably injured by the very cold weather of December, 1919.

TABLE VI. COMPARATIVE VALUES OF BROCCOLI STRAINS

Strain No.	Marketable heads	Small heads	No head	Cabbage cross	Cabbage cross marketable heads	Off type	Kale cross	Remarks
	%	%	%	%	%	%	%	
1.....	33.6	24.2	32.6	.....	.....	9.1	.....	Strain lacked vigor and uniformity. Large number producing no heads.
2.....	80.6	9.2	3.3	.....	.....	3.7	2.3	A superior strain showing good uniformity and little deterioration.
3.....	80.0	18.7	.....	.....	.....	1.7	.....	Very similar to No. 2.
4.....	77.2	21.2	.....	.....	.....	1.5	.....	Typical of some home-selected strains.
5.....	40.0	31.4	.....	20.0	5.7	2.8	.....	Bad cabbage-crossed strain of little value.
6.....	57.3	16.5	.....	10.9	1.8	6.1	6.4	

The number of strains being tested at the present time has been considerably reduced, those showing undesirable characters having been discarded.

SUMMARY

Summarizing the data obtained over a number of seasons, it is evident that there is a marked difference in value of strains, resulting in considerable variation of broccoli when packed and loaded in cars.

The practice of individual growers purchasing their seed from many different sources is to be discouraged. It is more desirable that the best possible strain be grown by one who is thoroughly familiar with seed growing, the seed itself being produced preferably in some Western Oregon growing section so that it may be acclimated.

RECOMMENDATIONS

It is recommended that those who are growing their own seed either for personal use or for sale, should have their seed plants inspected so that a superior and uniform type may be maintained. Such inspection service as is now being offered potato growers could be given to broccoli growers. In these various ways, fields of broccoli will become more uniform in character, suffering fewer losses from undesirable types, and the money value of the total crop will be considerably increased.

FACTORS AFFECTING SHRINKAGE AND CONDITION OF BROCCOLI

By A. G. B. Bouquet

An important factor in the ability of any vegetable to withstand long-distance shipment with the least deterioration in quality is the maturity of the crop at the time it is harvested. Car-loads of broccoli are shipped from Western Ogegon as far as New York City, necessitating a period in transit of 12 to 18 days. It is very necessary, therefore, that such a perishable product be harvested when in the best condition for long shipment, and that it be gathered, graded, and packed with the greatest care to avoid injury.

With the present increased freight rates, it is evident that it is undesirable to entail heavy expenditures for transportation, icing, etc., unless the broccoli is loaded when in the proper state of maturity. Over-ripeness of the curd (head) at harvesting time results later in a breaking down of the curd, separation of the various parts, loss in weight, limpness and wilted appearance following the removal of the product from the car. On the other hand, heads which are cut at a proper stage of maturity hold up in a superior manner when shipped. This is shown by the data presented in Table VII.

There is a tendency on the part of some growers to allow heads to get too old before cutting them, the assumption being that they will get larger with every additional twenty-four or forty-eight hours. As a matter of fact, the maturity of the heads, with their superior carrying qualities, is sacrificed for a possible increase in weight.

In the mind of the dealer to whom the crop is sold the most important characters of value in broccoli heads are: (1) whiteness of the curd; (2) solidity of the curd, showing no separation of its natural divisions; (3) size of the curd; (4) a green "jacket" of leaves encircling the head; (5) curd free from blemishes, black spots, finger bruises, molds, etc.

In order that data might be obtained concerning the behavior of heads which were cut in varying stages of maturity, certain crates of broccoli were harvested and then submitted to temperatures, in cold storage, as nearly as possible those under which broccoli are shipped to eastern markets.

The terms used in Table VII are defined as follows:

Heads are in "prime condition" when the curd is solid, showing absolutely no division, tight, color clear white.

Heads are "slightly over-ripe" when the curd shows some slight signs of segregation but is not plainly divided.

Heads are "over-ripe" when the curd plainly shows natural divisions, yet is turgid.

TABLE VII. SHRINKAGE OF BROCCOLI HEADS ACCORDING TO VARIOUS DEGREES OF MATURITY WHEN HARVESTED

Lot No.	Prime condition	slightly over-ripe	Over-ripe	Length of test
	%	%	%	days
1	15.8	22.8	25.5	11
2	10.5	17.5	23.0	12
3	14.0	22.0	31.0	17

The average loss in weight of the heads in Table VII was approximately 8 to 9 ounces per head of those harvested in "prime condition;" 13 to 13.5 ounces of those "slightly over-ripe;" and 16.9 ounces of those harvested "over-ripe." Figuring an average of ten heads per crate for the entire car-load, the loss per crate of the various degrees of maturity would be, respectively, 5 pounds, 5 ounces; 8 pounds, 2 ounces; and 10 pounds, 9 ounces. There is therefore a danger of increasing the shrinkage of a crate just twice the normal amount by allowing the heads to remain uncut

in the field. Added to this also is the fact that the appearance of heads harvested when over-ripe damages their chances of sale at a profit for the grower.

It is recommended that broccoli be harvested preferably when immature rather than when the heads show any signs of curd separation. By closer observation of the development of the heads in the field, a larger percentage can be marketed in "prime condition," thus insuring satisfaction to both grower and buyer and the greatest profit.

CHERRY BREEDING

By C. E. Schuster

Previous work by this Station has established the fact that the Bing, Lambert, and Napoleon (Royal Ann) cherries are both self-sterile and inter-sterile varieties. These varieties cannot be expected to bear much fruit when self-pollinated; neither will they bear fruit when pollinated by either one of the other two varieties. Where these varieties have been planted singly or in combinations, the crops have been very small or practically nothing at all. Many reports are constantly being received that cherry trees ten, twelve, and fourteen years old blossom profusely each year, but produce no fruit. Investigation of this condition generally shows that the trees belong to the Bing, Lambert, or Napoleon variety and are receiving no pollen from any other varieties.

While these three above-mentioned varieties are inter-sterile with one another, they respond readily to cross pollination from several other varieties like the Black Republican, Black Tartarian, or the Waterhouse. The first two varieties mentioned being unsuitable for canning, are not in general favor except for home use. The Waterhouse more nearly approaches the Napoleon in size, color, and solidity; it is more satisfactory to the canners as it brings a better price to the canning trade than any other of the varieties used for pollination. Two types of Waterhouse are in cultivation, the long-stemmed and the short-stemmed, of which the long-stemmed is the more desirable.

If one were to go back to the early history of horticulture in Oregon, he would find that the Napoleon was often propagated by means of seed. Many of these seedlings were inferior, while others were almost identical with the parent and worthy of being kept as orchard trees. They were sometimes known as Napoleon or Royal Ann seedlings; at other times simply as Napoleon or Royal Ann trees, and were often propagated by owners and set out in commercial orchards. From these orchards they were scattered by propagation in the nurseries over the State, and as a result we often have a Napoleon type rather than strictly a Napoleon variety. Many of these are more or less inter-fertile with the Napoleon, Bing, and Lambert varieties. This will undoubtedly explain the reason for partial crop of Napoleons in many of the commercial orchards where they have planted the Napoleon, Bing, and Lambert varieties in solid blocks.

Besides the problem of sterility, there comes up the question of susceptibility to disease. All of the sweet cherries are at times severely attacked by bacterial gummosis. On account of these problems, breeding work with cherries was started. Seed, resulting from crosses on these varieties by several other varieties, was planted in an endeavor to produce a new heavy-yielding variety of high quality, free from gummosis, self-fertile and inter-fertile with the Bing, Lambert, and Napoleon. A number of seedlings were obtained, some of which have been bearing for three or four years.

In the spring of 1920, eighteen of the more promising of these seedlings were placed under test for self-sterility. Over 3300 blossoms were bagged and allowed to self-pollinate. From these blossoms a number of fruits developed to one-third or one-half size and then shriveled up and dropped off, but not one developed to maturity, indicating a condition of self-sterility for all of these seedlings.

On the trees where the tests were being carried on, good crops of cherries were produced as a result of insect pollination. Due to the fact that there were many other seedlings blossoming in this lot, it is impossible to ascertain whether these eighteen promising seedlings were inter-fertile among themselves or were pollinated by pollen from the surround-

ing inferior trees. The question of inter-fertility or inter-sterility between these seedlings remains to be determined by further tests.

Resistance to gummosis is variable. Several of the better seedlings have records showing almost complete freedom from this disease, while others are very susceptible.

The surprising feature of the experiment has been the relatively large number of trees that have produced fruit of medium or excellent quality. Only those with excellent quality have been retained. One of those kept for further tests bears fruit as large as that of the Bing variety, but ripening with the Black Tartarian. Another one of the Napoleon type but larger than the Napoleon, ripens from a week to ten days ahead of the Napoleon. The last one to ripen is just taking color when the Lambert is ready to pick. Canning tests by the Horticultural Products section have demonstrated the adaptability of several for the canning trade. Others are firm and solid enough for shipment as fresh fruit. With all of the seedlings the question of inter-sterility or inter-fertility and the annual production of fruit per tree still remains to be tested out. Unless a seedling, after being carried through all the tests, is unquestionably of much greater value than any other variety now in cultivation, it will be discarded.

POLLINATION OF THE ETTERSBURG NO. 121 STRAWBERRY

By C. E. Schuster

Oregon strawberry growers have in the past been limited in the number of varieties of strawberries to about six; namely, Magoon, Oregon, Clark's Seedling, Gold Dollar, Wilson, and Marshall, of which the first four originated in Oregon. These are the most successful varieties, but none are entirely satisfactory. In an effort to procure a berry better suited to this State, a new variety has lately been introduced and widely planted. This is the Ettersburg No. 121, bred and introduced by Albert F. Etter of Ettersburg, California.

In growth, the Ettersburg No. 121 is exceptionally vigorous. The leaves will often stand up above the ground 15 to 18 inches, and a plant will probably make a larger hill than any other variety we have. It was originated in a section where ordinary varieties do not thrive, and is supposed to do better in the lighter soils, while in the heavier soils it has a tendency to produce a rank, vigorous, vegetative growth with small, poorly-flavored berries.

The fruit stalks are heavy and erect, holding most of the berries off the ground. The fruit is medium-sized, very solid, and of even color

Fig. 9. (A) Fruits from primary blossoms at the division points of the fruit stalk. (B) Secondary blossoms at the tops of the stalks. (C) Blossom that has just shed the petals in comparison with (D) a fully ripe fruit.

throughout, making it a favorite with canners, who class it as an excellent canning berry. Due to the fact that the fruit stalks are erect and the fruit very solid, the fruit is not as perishable during a wet season as that of many other varieties. It will stand a day or two longer than other varieties without being picked and suffer little damage to the berries.

Owing to its popularity with the canning trade and its reputation as a heavy bearer, this variety has been planted extensively during the last two or three years and especially during the spring of 1920. Varying reports have come in concerning it, from those entirely satisfactory and showing a heavy yield, to those unsatisfactory, stating that the variety was not bearing at all well in certain localities. On account of these varied reports an extensive study was made of the Ettersburg No. 121 during the blossoming season of the spring of 1920.

Each hill of this variety will produce from 15 to 50 fruit stalks, with each stalk normally divided into two or three branches. Each branch again divides once or twice and produces flowers on the end of each subdivision. In addition to the blossoms borne on the end of the stalk, some are also found at each point of division (Fig. 9.) This makes it possible to have twenty-two blossoms to a stalk, a number often found, although the normal number is below this, diminishing down to three to a stalk, with the average probably twelve to fifteen blossoms to the stalk. The blossoms at the division points will be referred to as primary blossoms and those upon the end of the subdivision as secondary blossoms.

The Ettersburg strawberry has a long blooming season, due to the fact that all the fruit stalks do not develop at the same time, and also to the progressive blooming of flowers on the same stalks. On an individual fruit stalk, the blooming starts with the lowest flower on that stalk, which is the first flower at the first division, and progresses toward the tip flowers on each subdivision. The first of the blossoms in 1920 at the Experiment Station at Corvallis, were noted about May 10. The plants were still blooming in the secondary blossoms on June 5. Due to the heavy foliage the first primary blossoms are not very much in evidence. The ones that come to notice particularly are the secondary blossoms, as these are visible above the heavy foliage, while the primary blossoms are usually found below the foliage. The first blossoms being below the foliage are quite well protected from ordinary frost. Foliage protection is quite a factor when comparing this variety with other varieties of light foliage, as the primary blossoms are very apt to be fully protected during the frost, while the secondary blossoms that extend beyond the foliage will usually be frosted. Due to the extended blossoming period, it will take repeated frosts to destroy the crop unless there is a heavy freeze.

In the first test carried out, the pollination was done on both primary and secondary blossoms. At the time that the count of the set of fruit was taken, it was noted that almost all of the primary blossoms were setting fruit, while few, if any, of the secondary blossoms were fruiting. Results showed that the amount of fruit was proportionate to the number of primary blossoms. Of 929 blossoms, 336 were primary, while from the total number of blossoms, there were set 338 fruits, showing that a very few of the secondary blossoms set fruit. Later on a test was run with secondary blossoms exclusively, and of 849 used, 109, or about 13 percent, set fruit. The lack of set fruit on the secondary blossoms is a thing that attracts the eye most. These are the ones exposed above the leaf surface and their failure to set fruit undoubtedly has been in a large part responsible for the reputation of the Ettersburg No. 121 as a light bearer.

Pollen from the Magoon, Oregon, Wilson, and Clark's Seedling was used to cross-pollinate the Ettersburg No. 121, but the percent of set was approximately the same as from self-pollinated blossoms. All evidence indicates that the Ettersburg No. 121 is self-fertile and that cross-pollination does not increase the yield.

Counts made of the berries on plants pollinated by insects showed approximately the same proportion of berries on primary and secondary blossoms as on those that were cross-pollinated or self-pollinated under test.

In the secondary blossoms that do not set fruit, both pistils and stamens are present. The number of pistils is usually much smaller than in the primary blossoms, but the few pistils present are apparently fully developed and at the proper stage of maturity have the stigma covered by the usual sticky secretion. The stamens usually are full size. Thus we find both sexes present in the same flower, but only about 13 percent of the secondary blossoms set fruit. It may be that the inhibiting influence in non-fertilization is directly connected with small numbers of pistils.

The primary blossoms number about 50 percent to 54 percent of the total number of blossoms. Tests showed that 13 percent of the secondary blossoms set fruit so it would seem that 50 percent to 60 percent of the total number of blossoms can be counted on to bear fruit. With plants bearing 150 to 600 blossoms each, the variety, under normal conditions, will bear all the fruits the plants are capable of maturing to good size.

Fig. 10. (A) Fruits from primary blossoms. (B) Secondary blossoms. (C) Fruit from secondary blossoms.

DEPTH OF PLANTING IN RELATION TO TREE GROWTH

By Henry Hartman

From the time when fruit trees first began to be transplanted there have been differences of opinion concerning depth of planting. Some have contended that the depth of planting should be that of the nursery row or original habitat. Others have believed that the original depth is insufficient.

To test the validity of these various opinions, a depth-of-planting experiment was undertaken by the Station at Corvallis. In the spring of 1915, a plot of ground of the experimental farm was set aside for this work. Upon this ground trees of two varieties of apples, namely, Esopus Spitzenburg and Gravenstein, and trees of Anjou pears and Italian prunes, were set out at varying depths. Five trees of each variety were used in each block, and the depth of planting ranged from that of the nursery to as much as twenty-seven inches below that of the nursery. The trees used were one and two years old. Observations of the growth and vigor

Fig. 11. Esopus Spitzenburg tree set 15 inches below nursery depth. At end of four years no roots have developed above original crown. Note upward tendency of root growth. Depth of planting indicated by dotted line.

were made from time to time, and at the conclusion of the work (fall of 1920) an examination of the root system was made.

The results of this experiment are at least interesting in a negative way, if not of material value to the practical horticulturist. Strange as it may seem, neither the early records of the experiment nor the present condition of the trees, reveal any striking differences in size and vigor of tops or caliper measurement of trunks. So far as the trees used in this test are concerned, depth of planting seems to have made but little difference, this being generally true of both the one- and two-year-old trees, and of all the different fruits and varieties concerned. Variation in size and thrift occur, of course; but these can be accounted for by variations in soil, individuality of trees, and other factors aside from depth of planting. It must be borne in mind, however, that the trees under observation were all comparatively young at planting time, and that while depth of planting seems to have made but little difference with them, there is a possibility that the same results would not be obtained in transplanting trees that are older and consequently less adaptable to varying conditions.

The examination of the root system revealed some significant facts. As a rule the original root systems seem to have made considerable growth, this being true even with the trees planted at excessive depths. In all cases of deep planting, however, the usual tendency of growth of the original roots was toward the surface of the soil.

The observations relative to the development of roots above the grafts were especially interesting. The common opinion has been that deeply planted trees soon develop roots above the graft or crown and that these in turn tend to supplant the original root systems. This opinion was not entirely borne out by the observations. For instance, with the pear trees, no case was found where roots had developed above the graft. The deeply planted apple trees developed some roots above the original system, but in no instance did these assume real importance. With the prune trees, a considerable number of roots were formed above the grafts, but these did not correspond in amount to the development of the tops of the trees. Too wide conclusions, however, regarding the tendency of trees to develop roots above the grafts should not be drawn from the results of this experiment. Work by other investigators shows quite clearly that the ability of trees to develop new root systems varies a great deal with the different fruits and varieties. So, while the results given here may be applicable to the sorts in question, it is quite probable that they would not obtain in all cases.

FERTILIZER EXPERIMENTS WITH FRUITS

By L. P. Wilcox

A few years ago the Hood River Experiment Station conducted fertilizer experiments on several apple orchards in the Hood River district. Nitrate of soda was found to be a quick-acting stimulant for devitalized apple trees. Continuing this work, the Horticultural department of the Oregon State Agricultural College has applied this fertilizer to prunes, pears, and red raspberries in various fruit districts of Western Oregon, and the results were closely observed and recorded. Practically in all cases, beneficial results were obtained.

NITRATE OF SODA ON ITALIAN PRUNES

Early in the spring of 1919, at least one month before blossoming time, the fertilizer was applied to the soil, in the dry or crystalline form, being spread broadcast upon that area occupied by the feeding roots of the tree. Amounts used varied from 3½ to 5 pounds to the tree, the most satisfactory results coming from the use of the latter amount.

In case of A. F. Stearns' orchard at Oakland, Oregon, the trees are rather old and had evidently consumed most of the available plant food in the soil, but upon the application of five pounds of nitrate of soda per tree, the following results were noted:

	Nitrated plot	Check plot
(1) Color of foliage	Dark green	Yellowish green
(2) Terminal growth	5 to 8 inches	Poor, non-vigorous
(3) Appearance	Vigorous, strong	3 to 4 inches

This strong, vigorous, dark-green growth made a very remarkable contrast with the remainder of the orchard and could be easily seen by everyone passing. As for the influence upon the fruit, the following results may be of interest:

	Nitrated	Check
(1) Fresh fruit, net weight	30 lbs.	30 lbs.
(2) Size of fresh fruit	12 to the lb.	13 to the lb.
(3) Size of dried fruit	35 to the lb.	37 to the lb.

The temperature of the tunnels and length of time in drying were the same for both lots, 180° F. for twenty-eight hours.

From these figures it would be deduced that a larger fresh fruit is obtained, which carries this increased size through the drying process, giving thus a larger dried product. Regardless of this increased size, the moisture content must have been the same as in the check prunes, for the same temperature was used and the same length of drying time.

Another interesting orchard was that of Mr. Jones in the Lookingglass district south of Roseburg. These trees were ten to twelve years old, so five pounds of nitrate of soda was applied per tree as given in the above case. By the first of August of that same year, a comparison between the fertilized and non-fertilized trees could easily be seen. In case of the fertilized trees, the leaves were larger, darker green in color, thicker in texture with a leathery appearance, and did not tend to curl during the hot weather. The terminal growth was strong, averaging from 100 to 150 percent increase in length.

Here again the fruit seemed larger, but was about a week later in maturing. This prolonged maturity may be beneficial in years when the rains come early, as the immature fruits do not crack as readily as the ripe fruit. If the rains continue as in the fall of 1920, however, the prolonging of maturity would not be of any value.

In Mr. Harry Woods' Italian prune orchard at Dallas, Oregon, similar beneficial results were obtained regardless of the fact that the soil and weather conditions encountered were entirely different from that of

Southern Oregon. These trees were sixteen to eighteen years old and showed lack of proper vigor. The soil is from a semi- to red-hill type and light in texture. Here again five pounds of nitrate of soda was applied early in the spring and the following results tabulated:

	Nitrated plot	Check plot
(1) Average terminal growth	6.97 inches	3.70 inches
	Width Length	Width Length
(2) Average size of leaves	1.93 in. 4.51 in.	1.67 in. 3.99 in.
(3) Color of leaves	Dark green; vigorous	Light, almost a yellowish green

Influence upon the fruit:

(1) Maturity of prunes prolonged one week.
(2) Increase in number of prunes per tree, approximately 33 1/3%.
(3) Increase in size of prunes, 10%.
(4) No noticeable difference in time required for drying.
(5) The dried product held the same ratio as was seen in the comparison of the green fruit.

These results were so convincing that the owner has since applied fertilizer to his entire acreage and deems it an advisable investment.

In all cases where this fertilizer was applied to prunes, there was a response to the stimulant, more noticeable, however, in their vegetative parts than in their fruits.

NITRATE OF SODA ON RED RASPBERRIES

Knowing the effect of nitrogen upon the vegetative parts of a plant, it was thought new cane growth would be benefited if nitrate of soda were applied to cane fruits.

Two hundred and fifty pounds of nitrate of soda per acre was applied to Mr. Stratton's red raspberry plantation near Brownsville, Oregon. This application was made early in the spring when the new canes were from two to three inches in length, scattering the fertilizer broadcast upon the soil within a radius of fifteen inches from the plants.

The results were as follows:

	Nitrated plot	Check plot
(1) No. of berries per box	254	270
(2) Color of berries	Dark pinkish red with luster	Dull pinkish red
(3) Time of maturity of berries	3 to 5 days earlier	
(4) No. of new canes to plant	5 to 8	3 to 5
(5) Average length of new canes	63 in.	59.7 in.
(6) Color and appearange of foliage	Dark green, vigorous	Lighter green
	Width Length	Width Length
(7) Average size of leaves	2.95 in. 4.40 in.	2.67 in. 4.10 in.
(8) Percent of increase in crop	10 percent	....

The above figures show that a larger berry with a better color or luster resulted as well as a stimulation of cane growth—more canes per plant and also larger canes, which in turn would normally produce a larger crop of fruit the coming year. This added stimulant, however, caused the canes to continue their growth in the fall and winter, and the extreme temperature of the winter of 1919 and 1920 caused considerable killing back of the canes and reduced the 1920 crop to less than 10 per cent normal.

Results of 1920 verify the fact that cane fruits can be stimulated into a more vigorous growth by the use of nitrate, but caution should be emphasized on the part of the grower, to prevent the forcing of vegetative growth late in the fall, resulting in winter injury, as of last season.

From the results given above we see that nitrate of soda is a quick-acting stimulant, bringing our devitalized trees and plants back into good vigor; but there is a danger of over stimulation, when this fertilizer is applied as a year-after-year practice, causing the trees to make vegetative growth at the expense of fruit production.

Most of the soils upon which devitalized orchards are growing, lack the proper amount of humus, which can be supplied only by the application of manures or the turning under of cover crops.

The work done so far would suggest that the best possible cultural method would be to use nitrate of soda as a quick-acting stimulant to restore vigor, and then retaining this vigor by building up the soils through growing and plowing under of certain cover crops.

SOME INVESTIGATIONS ON PRUNE DRYING

By Ernest H. Wiegand

Preliminary investigation was started on prune drying during the fall of 1919. This investigation was primarily on air flow, temperature, and humidity in Oregon-type tunnels. The Oregon tunnel drier, which ranges from 22 to 25 feet in length, is the drier that should be constructed by the growers. At present, due to diversified opinion, there is no standard drier in Oregon. Experiments in drying have shown that the so-called Oregon tunnel type of drier more nearly meets the needs of the grower. Experiments were carried on in the tunnels at the Horticultural Products Building. Field investigation consisted in testing driers erected by growers in different sections of the State. Due to the fact that the Horticultural Products Building was being remodeled this fall, experimental work was considerably curtailed.

The methods of harvesting prunes in Oregon vary from one locality to another. In some localities the fruit is harvested from the ground as it falls naturally, while in others it is the common practice to shake the trees vigorously in order to expedite harvesting. In experiments conducted in 1911 Messrs. Lewis, Brown, and Barss* found an increase in the weight of prunes harvested after they had dropped naturally as compared with those shaken off. This increase, they contended, probably meant that 11 percent of the entire sugar had formed in a very short space of time. Chemical changes are constantly taking place in the prune during its period of ripening. To hasten picking would mean a considerable loss in weight and size to the grower. At the end of the season when only a few prunes still remain on the trees, a slight shaking may be resorted to. Premature harvesting may be avoided by allowing

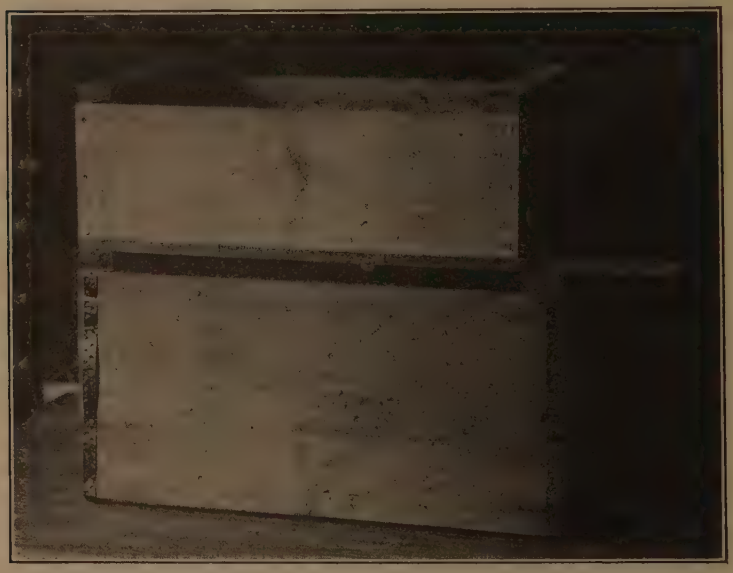

Fig. 12. Comparative size of California lug and field box.

the prunes to drop naturally. Messrs. Lewis, Brown and Barss[5] found a loss by premature harvesting amounting to 6 percent of the total weight of the crop.

Much can be said for and against the use of the field box in handling prunes from the orchard to the drier. This box, holding on the average of sixty pounds of fresh fruit, is unwieldy and unsanitary, causing the fruit to mash, besides promoting the development of brown rot (**Sclerotina ceneria**) in case the fungus is present. The use of the lug box commonly used in California would in a great measure reduce the loss, especially in wet years when the brown rot is more prevalent and the fruit becomes soft before harvesting. Less bleeding and overheating would occur at the drier if the fruit were allowed to remain standing in this type of orchard box. The lug box is smaller than the field box. Fig. 12. The inside dimensions are as follows: 16½ inches long by 14 inches wide and 6 inches deep.

Experiments conducted in 1919-20 have shown that grading will save much of the labor incident to sorting after drying. In order that all of the prunes may be thoroughly dried, the drying of the majority of the prunes on the tray is carried too far. Much of the green and immature

[5]Lewis, C. I., Brown, F. R., and Barss, A. F. Oregon Agricultural Experiment Station Bulletin 145, pages 7 and 9, 1917.

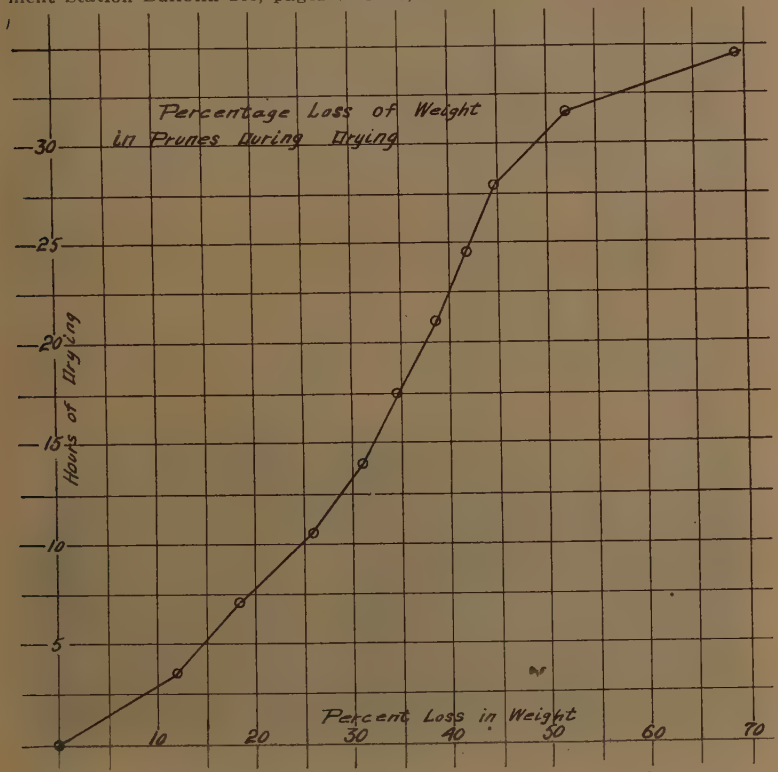

Fig. 13. Percentage loss of weight of prunes during drying.

fruit dries very slowly, and by the time this is dried the other fruit on the tray has overdried. This accounts for the large amount of overdried fruit on the trays.

The loss to the grower in wasted moisture due to overdrying amounts in most cases to 10 percent. If the fruit is carefully watched when drying is nearly complete, almost the exact amount of moisture necessary for good quality can be retained. This amount of moisture is from 22 to 24 percent.

The following curve is the average of twelve determinations on the loss of weight in drying. These figures were obtained by weighing twelve trays at periods of three and one-half hours throughout a thirty-five-hour drying period. The total loss in weight was 69.4 percent.

Many growers are adopting the lye dipping, sorting, and spreading machines for the purpose of dipping and grading the fruit before drying. This method is efficient and less costly than other methods of grading. If two men are used in traying, it will be possible to eliminate most of the green or immature fruit from the trays. This fruit usually occupies 5 percent of the tray space.

Prunes are usually dipped in cold water, boiling water, or boiling lye solution before drying. The object of this dipping, with the exception of the first case, is to hasten drying. This is accomplished by checking the skin of the fruit with boiling water or boiling lye solution.

In many cases the prunes are spread directly on the trays by hand without dipping or washing. This is not a good practice as in most cases dirt adheres to the fruit and makes a very unclean product. If the fruit cannot be dipped in hot water, it should at least have a preliminary washing in cold water before it is trayed.

The use of boiling water as a dip for prunes is a good practice. Some growers use this method entirely in preference to the lye, and assert equally as good results. In tests conducted by the Horticultural Products section, it was found that the drying time could be reduced from two to five hours by using boiling water in place of cold water. If the prunes are properly handled, that is to say, if boiling water is used with a good cold dip immediately following, almost the same degree of checking will occur as with lye. The water must be kept at boiling temperature in order that checking will result.

Comparing boiling water and lye dipping, the time of drying favors the latter method. It was found also by Messrs. Lewis, Brown, and Barss[6] that the drying time could be reduced by using hot lye solution.

[6]Lewis, C. I., Brown, F. R., and Barss, A. F. Oregon Agricultural Experiment Station Bulletin 145, page 14.

TABLE VIII. EFFECT OF LYE IN DIPPING PROCESS.

Dipped in lye	Weight fresh	Weight dry	Dried fruit	Drying time
	lbs.	lbs.	lbs.	hrs.
Prunes grown on upland	427	151	21.27	36.00
Prunes grown on upland, green	438	140	19.17	38.00
Prunes grown on lowland	490	169	20.36	37.00
Prunes grown on lowland, partly dried on ground	444	150	20.27	43.00
Total average	1799	608	20.27	38.50
Dipped in boiling water				
Prunes grown on upland	491	176	21.46	42.00
Prunes grown on upland, green	439	143	19.60	45.00
Prunes grown on lowland	495	151	19.27	45.33
Prunes grown on lowland, partly dried on ground	266	99	22.33	43.00
Total average	1691	569	20.66	43.80

Too often the grower relies on the lye solution alone rather than on the heat in connection with the lye to obtain the necessary checking.

The lye solution used in the tests conducted by the Horticultural Products section was one pound of lye to thirty gallons of water. It was found that an increase of lye did not add materially in the checking ability of the solution, the heat being the main factor.

Effect of treatment on drying time can be readily noted in the following table. The number of hours given was the average taken from sixteen test trays in each case and dried under the same conditions of temperature, humidity, and air flow.

Treatment	Average number of hours for drying
Undipped	50.6
Cold water dip	50.0
Boiling water dip	44.7
Boiling lye dip	36.6

In the methods of treating prunes before drying, sanitary handling should not be overlooked. Fresh water should be used thoroughly to cleanse the prunes after they come from the hot baths. In the cleansing bath a constant change of water is necessary; otherwise this water becomes muddy by the soil washed from the fruits.

The hot water and lye solution have the further beneficial results of inhibiting the brown rot when this is prevalent. Some growers use the lye solution entirely for this purpose, but we have found that when boiling water is used for dipping it is possible to obtain very nearly the same results.

Before building a drier the grower should first study local weather conditions very thoroughly. In the construction of the natural-draft type of driers, much depends upon the local conditions. The direction of the prevailing winds should be observed so that the drier may be located to take advantage of the maximum amount of air circulation, or in other words, in line with the prevailing winds. Care must be taken, however, not to place the drier in an extremely exposed place.

The location of the drier should be considered in order to facilitate handling of the fruit. A side hill with the right exposure, if near enough to the orchard, makes an ideal building site and has the added advantage of decreasing the cost of construction. It also adds to the ease in un-

Fig. 14. Front elevation of Wm. Fry drier, Yamhill, Oregon, showing receiving platform and side-hill location.

loading of the fresh fruit at the receiving platform. This is illustrated by Fig. 14.

After having decided on the location, the type of drier should be considered. A careful study has been made of this subject, and as a consequence we can say that for cost of construction, cost of operation, ease of handling, and quick drying, the tunnel drier is the type to choose. Some growers, however, give too much thought to the question of type rather than the conditions under which their fruit is being dried. Type does not determine quality, but conditions within the drier do.

Fig. 15. O. E. Fry drier, West Salem, showing fresh air intakes in furnace chamber.

The tunnel type has been used in Oregon for many years. Changes in construction have been made in many instances, but from the standpoint of operating costs it has stood the test of time. This type will be the easiest to change in order to regulate existing conditions within the drying chamber. This alone is reason enough for choosing this type of drier.

When the type of drier has been selected, see if the following conditions can be maintained: (1) rapid air movement, (2) uniform temperature, (3) medium high humidity.

Frequently we find that the furnace chambers of the driers have insufficient air openings. Drying is retarded, although the temperature is maintained at the critical point. This slow drying is caused by the reduced circulation of fresh air.

A deep furnace chamber combined with adequate air intakes (as in Fig. 15) and sufficient radiating surfaces will materially assist in increasing the movement of air in the dry chamber. A shallow furnace chamber prevents rapid circulation and therefore increases the risk of scorching the fruit.

Data collected from driers built during 1920 will show the difference in air movement between deep and shallow furnace chambers.

TABLE IX. SHOWING AVERAGE AIR FLOW, IN FEET, OF FOUR DIFFERENT DRIERS.

Drier tested	Depth of furnace chamber	Fresh air intakes on furnace chamber	Temperature of tunnel	Air flow per minute (lin. ft.)
	ft.			ft.
No. 1.....	11	3 openings 8″x10″	180° F.	120
No. 2.....	11	3 openings 8″x10″	180° F.	115
No. 3.....	9	8 openings 10″x12″	165° F.	250
No. 4.....	16	11 openings 8″x18″	142° F.	376

Another common defect is the limited-size openings or throats from the furnace chambers into the tunnels. The area of furnace-chamber openings should exceed the area of the cross section of the drying chamber.

The outlet for the used air should equal in size the cross-section area of the tunnel less the cross-section area of the trays. This will prevent any retarding effect on circulation of the air from the furnace chamber to the outside air.

The stack will in some measure determine the speed of the air flow, but the following fact must be taken into consideration. As the warm air, carrying from 30 to 35 percent moisture, passes up through the stack and cools, it shrinks, becomes heavier per unit of volume, moves more slowly, and will ultimately hinder circulation if the stack is built too high. Many growers have found short stacks to give rapid air circulation, much better than where the stack was twenty to twenty-five feet in height. To test the air flow in the tunnel drier, an anemometer can be used. This may be purchased from any scientific instrument supply house. The anemometer will read the air flow in lineal feet direct, and it is a common practice to record these data in lineal feet per minute.

The humidity is the next consideration. Growers have found that they often have scorching at 180° F. This is generally caused by too low humidity. Dry heat closes up the pores (lenticles) through which the water should escape. In some instances the openings are glazed over by sugar and in others the retarding action is set up by the fruit itself. This is due mostly to lack of moisture in the air passing over the drying fruit. When rapid evaporation is taking place from any fruit, that fruit is very much cooler than the surrounding atmosphere; caramelization of the sugars, therefore, cannot take place if this rapid evaporation is maintained.

To increase the humidity of the in-going air, the use of moisture pans has been found to be of benefit. In experiments conducted during 1920, it was found that by flooding half the floor of the furnace chamber in the drier in the Horticultural Products Building, the resulting increase in humidity prevented, in a great measure, the charring of the fruit. This increase in humidity did not hinder rate of drying in any instance. The relative humidity after the air had passed over the fruit was found to be only 30 percent.

A high humidity has a tendency to open the pores, and when high humidity and rapid air movement can be obtained at the same time the drying time will be materially decreased. A high humidity with a very slow movement of air should be avoided, as this retards the rate of drying.

SUMMARY

(1) Use of shallow, six-inch lug boxes will facilitate handling of prunes and decrease amount of spoilage.

(2) Boiling water or lye dipping will materially hasten drying.

(3) Sorting and grading before drying will reduce the cost of handling dried fruit.

(4) Air flow in drying chamber is increased by having larger air intakes, deep furnace chamber, and shorter stacks with larger cross-section area.

(5) Higher humidities are beneficial when accompanied by rapid air movement.

Part II

Report

of the

Department of Entomology

THE WESTERN PEACH AND PRUNE ROOT BORER

(*Sanninoidea opalescens* Edw.)

By Frank H. Lathrop and A. Burr Black

INTRODUCTION

Since the earliest days of orcharding in Oregon, the root borer has been the most serious insect pest with which prune growers have had to contend. In spite of the large amount of study that has been devoted to the control of this pest, no really satisfactory method of control has as yet been established.

For a number of years this Station has been conducting an investigation of the control of the root-borer. In spite of the fact that this project has been vigorously and carefully prosecuted, our results have been largely negative. The very nature of the pest makes investigation difficult, leads to conflicting evidence and renders results uncertain. This necessitates long-continued and large-scale work to substantiate results and establish a successful method of control.

We hope that we can soon recommend an economical and effective control, and we shall give any new information to the growers as soon as it is gained. We shall not make any definite recommendations of new treatments, however, until they have been thoroughly tested and their advantages and disadvantages thoroughly understood.

We include in this paper a brief review of our work of investigation in order that the growers themselves may realize more clearly the nature of the problem and the manner in which it is being attacked.

HISTORICAL

Evidence indicates that the peach and prune root borer of the Pacific Coast region is a native species which infested wild stone fruits even before the first settlers entered this section. Hence, the insect made its attack upon peach and prune as soon as those trees were planted in the newly-settled districts, and the importance of the presence of the root borer from a horticultural standpoint was recognized as soon as commercial orchards were established. In California, methods of control were promulgated as early as the middle eighties. Within a few years the rapid development of the prune industry in Oregon focused the attention of the growers upon the pest in this State and in 1890 Washburn[1] stated that "this is without doubt one of the worst pests with which Oregon orchardists have to contend."

Because of the similarity between the Western peach and prune root borer and the peach-tree borer of the East, the history of the campaign against this pest on the Pacific Coast is merely a new chapter of an old story. During the century or more in which the fight had been waged in the East, washes and treatments of almost endless variety had been suggested and unsuccessfully tried as a means of control. When the fight was taken up in the West, the methods employed were along the same lines as had been employed against the Eastern pest. The various washes and treatments proved as unsatisfactory on the Pacific Coast as they had on the Atlantic.

The investigation in the West brought out several innovations, which for a time promised excellent results, but which, one by one, resulted in ultimate failure, and the workers fell back to the stock recommendation, "dig the borrers in fall and spring." Woodworth[2] in 1902 reported upon extensive tests of carbon disulfide in killing the worms in their burrows. Contrary to earlier results in the East, his work showed this material to

[1] Washburn, F. L., Ore. Agri. Coll. Expt. Sta. Bul. 5, page 8, 1890.
[2] Woodworth, C. W., Calif. Agr. Expt. Sta., Bul. 143, 1902.

be effective and that, with great care, the treatment could be applied without serious injury to the trees. Later investigation has shown, however, that this treatment cannot be employed in commercial orchards without danger of excessive injury to the trees.

About this time, orchardists in the Santa Clara Valley of California, under the leadership of Mr. D. B. Pickering, began the use of heavy crude oil.[3] The oil was applied as a paint to the bases of the trees. At the outset, results seemed satisfactory, but again the danger of injury to the trees proved too great to justify the treatment.

More recently Morris[4], experimenting with the use of asphaltum applied to the bases of the trees, reported this treatment to be from 95 to 98 percent effective. Further tests in several states, however, have shown this treatment to be unsatisfactory.

Recent Investigations. Recent investigations of new treatments or promising materials include the work of Blakeslee[5] with paradichlorobenzene, and the work of Peterson with miscible oils[6] as ovicides, and with sodium cyanide[7] as a larvicide. Apparently the oils are ineffective as ovicides, while the results with paradichlorobenzene and sodium cyanide are not yet conclusive.

Investigation of Control in Oregon. Investigations of the control of the root borer in Oregon were begun by the earliest entomological workers. Washburn and Cordley both made observations on the life-history and habits of the pest, and tested methods of combating the insect. The early publications, however, were largely in the nature of recommendations of previously-tested treatments, rather than reports upon investigations of new methods.

In 1916 the investigation of the Western peach and prune borer was taken up as a major project by this Station with Mr. G. F. Moznette in direct charge of the work. Mr. Moznette made extensive tests of a large number of the more promising washes, and of various grades of asphaltum and tree paints.

In 1917 Mr. Moznette resigned, and the project was continued by the senior author. Especial attention was given to the development of washes and protectors which it was hoped would prove effective in excluding the borers from the trees. The use of asphaltum upon trees of various ages was further tested, but this material proved so unsatisfactory that investigations along this line were practically discontinued.

With the restoration of the Crop Pest Act in 1919, it became possible to conduct these investigations on a really satisfactory basis. The junior author has been enabled to give practically full time to the project during the summer of 1919 and a portion of the summer of 1920. Comparatively large scale tests were made of promising treatments which had been developed in the course of our previous investigations, and particular attention has been given to the development of washes and sprays with the hope of finding a simple, economical, and effective method of combating the pest.

During the past few years, close observations have been made on the life-history and habits of the pest, with the result that many new and valuable facts have been established.

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[3]Ehrhorn, E. M., Calif. Hort. Comm. Bien. Report, I, 113, 1905.
[4]Morris, E. L., Calif. Agri. Expt. Sta., Bul. 228, 1912.
[5]Blakeslee, E. B., U. S. Dept. Agri., Bul. 796, 1919.
[6]Peterson, Alva, Jour. Econ. Ent., XI, pp. 46-55, 1918.
[7]Peterson, Alva, Jour. Econ. Ent., XIII, pp. 201-208, 1920.

PLATE III

A. Peach tree practically girdled by continual attacks of root borers. B. Adult moth, at rest. C. Eggs on prune bark (magnified). D. Larva (enlarged). E. Larva in winter cell (enlarged).

INJURY

The characteristic injury resulting from attacks of the peach and prune root borer is well known to growers of these fruits. The presence of the pest is usually first called to the attention of the grower by the masses of gum and frass exuding from the bases of infested trees. Examination of an infested tree will show one or more tunnels just beneath the bark at the crown of the tree. These tunnels usually begin just above the soil surface and extend downward, usually to the depth of several inches. If the examination is made in late summer or during the winter or early spring months, the white, grub-like larvae will be found in the tunnels.

As a result of a combined attack of several larvae the tree may be completely girdled and killed. More often the tree is not killed outright, and the attack results in diminished vitality and a reduced yield of fruit.

It is the cumulative effect of continual infestation season after season which proves most destructive to the trees. New tunnels are formed before the old ones heal, and large areas of bark and cambium at the crown of the tree are killed. Fungous rots gain entrance here, and the tree is soon rendered worthless and ultimately killed.

Healthy Trees Attacked. In orchards under our observation we have frequently found that trees of sickly appearance showed the heaviest infestation. These trees almost invariably showed severe injury which had accumulated through the attacks of several seasons. It seems that this condition has led some growers to the conclusion that only devitalized trees are attacked. We have found in the course of these investigations, however, that attacks are by means limited to devitalized trees, and heavy infestation is frequently found in trees which to all appearances are perfectly healthy and in an excellent state of vitality.

We have never observed a severe infestation of cherry trees by the root borer. Butcher,[5] however, reports such attacks in California, where the root borer proved to be a serious pest in commercial cherry orchards.

HOST PLANTS—VARIETAL SUSCEPTIBILITY

In our studies we have found that the several kinds of stone fruits show considerable difference in susceptibility to attack by the root borer. Almond is decidedly the most subject to infestation, followed in order by peach, apricot and prune. There seems to be little difference in this respect, between peach and apricot, while there is a much more appreciable difference between peach and prune. There have been reports from several sources that prunes grafted on Myrobalan plum stock are practically immune to attack. In our work we have found no evidence to support this claim.

LIFE-HISTORY

Winter Condition. The winter is spent in the larval or "grub" stage. The larvae are more or less active during warm weather and it seems probable that growth takes place during such periods. Our observations show that during periods of cold, rainy weather the borers leave their tunnels in the bark, and work in the gum and frass as well as the soil immediately surrounding the base of the tree. Many of these "worms" lie dormant in silken cells which they spin against the tree trunk beneath the soil surface. This habit of forming winter cells seems to be much more pronounced in heavy, wet soils, than on the more porous types.

Spring Activity. With the approach of spring, the larvae become more active. The oldest borers soon leave their tunnels, and spin cocoons of silk and frass. Cocoons have been found at Roseburg as early as April 22, although they were not found in numbers until late in May and early June. In more northern portions of the State, it appears that the formation of cocoons and the emergence of adults occur later than in the more southern districts.

[5]Butcher, A. C., Monthly Bul. Calif. St. Comm. Hort., III, pp. 318-326, 1914.

Emergence of Adults. The adults, which emerge from the cocoons, are very dark, steel-blue, "clear-wing" moths with a wing expanse slightly more than an inch. These moths are active by day, and have much the appearance of dark-colored wasps as they fly rapidly back and forth through the orchard.

Moths first appear during the latter half of June. The great number of moths appear during the month of July, but they continue to emerge and deposit eggs throughout the summer.

Egg Deposition. The females begin depositing eggs about July 1, and the period of heaviest oviposition occurs during the middle of that month. The number of eggs deposited decreases from that time until early fall, when oviposition ceases.

The egg is a tiny, flattened, oval, disc-shaped object of a deep chocolate-brown color. The eggs are ordinarily deposited on the trunks of the trees, most commonly within twelve inches of the ground.

Each female is capable of producing from three hundred to eight hundred eggs.

Larval Activity. The eggs hatch within ten days, when the young larva gnaws its way through the egg shell, and seeks entrance into the tree. When the tiny borer finds a suitable place in the bark, it tunnels in, and a small pile of frass marks the point of entrance.

The young borer lives for a while in the outer layers of bark, leaving a tortuous tunnel of indefinite length and direction. When the larva grows larger it burrows deeper into the bark, forming the comparatively larger cavities in the inner bark and cambium which constitute the characteristic injury.

The larva is a grub-like "worm," pale yellowish or white in color, with a dark brown head. When fully developed, the larva is approximately an inch and a quarter in length.

A Single Generation. Because of the long period of egg laying, larvae of all sizes may be found within the tree at almost any season. This gives the insect the appearance of passing through several generations during the year. Such is not the case, however, and there is but a single generation.

CONTROL MEASURES

Natural Control. Only a very small percentage of the eggs which are deposited ever produce adult moths. This reduction in the number of borers living through to maturity is the result of a number of natural factors. Among these may be mentioned failure of the newly-hatched larvae to penetrate the bark of the tree, fungous and bacterial diseases, parasitic and predaceous insects.

In the course of our investigations, we have observed that of the many larvae which hatch from the eggs, comparatively few gain entrance to the tree.

We have found numbers of larvae which had been killed by disease, apparently of both fungous and bacterial origin. While we have made no attempt to keep accurate data on this point, it is apparent that these diseases of the larvae constitute an important influence in reducing the number of the borers.

Parasitic insects were not uncommon. One species, *Itamoplex tejonensis* Cresson,[9] was found to destroy about three percent of the pupae within the cocoons collected at Roseburg during the summer of 1919. Predaceous insects would seem to be of less importance, although a number of ground beetles were observed which no doubt played some part in destroying the larvae.

Applied Control. While the natural control is of great importance, it is not sufficient to prevent serious injury to the trees. To reduce

[9]Determined by R. A. Cushman, U. S. Dept. of Agri., Bureau of Entomology.

infestation sufficiently to prevent this injury, growers have resorted to various treatments.

Worming. "Worming" or removing the borers from the trees has for many years been the standard treatment for the root borer. Today it remains the most thoroughly reliable method yet devised.

The worming may be done at almost any season, but spring and fall are preferable, for at these seasons no new borers are entering the trees. In cases of severe infestation, it is advisable to worm the trees in the fall, after September 1, and repeat the process in the spring, before July 1. Where infestation is less severe, the spring treatment should be sufficient.

No special tools are necessary. A heavy-bladed sharp knife is essential, and a small trowel will be found convenient. The soil should be pulled away to expose the bases of the tree trunks. The tunnels are then opened, the larvae removed and destroyed. The work should be carefully done in order to remove all larvae and to avoid undue injury to the trees. The knife used should be sharp, and clean cuts should be made. It is well to apply an antiseptic solution, such as bordeaux, to the wounds before replacing the soil.

INVESTIGATIONS OF OTHER METHODS OF CONTROL

The process of worming is a tedious and expensive procedure. It is difficult to find and remove all of the larvae, and, for this reason, the process is often ineffective. It has been our endeavor throughout the investigation of this pest to devise some simple, economical, and effective treatment that would obviate the necessity of worming. We here briefly summarize the treatments which we have tested, and the results which we have gained.

Experiments of 1916

The treatments listed below were applied during the spring and summer of 1916 by Mr. G. F. Moznette. The results were checked in part by Mr. Moznette before leaving the Oregon Station, and further data as to the efficacy of the treatments were obtained by the senior author after the departure of Mr. Moznette.

Tree Washes.

Lime—crude oil mixture
Lime-sulfur—salt mixture
Lime—coal tar—whale oil soap mixture
Shaker wash
Soap—soda—carbol wash
Hydraulic cement wash
Hale wash
Missouri wash

Asphaltums, etc.

Solid asphaltum (grades "C" and "D")
Asphaltums (solid and liquid with and without whitewash)
Liquid asphaltum (with and without arsenicals)
Tocoseal
Tocobond
Tanglefoot
Sherwin-Williams Pruning Compound.

Mechanical Protectors.

Scott tree protectors.

Discussion of Results, 1916

None of the washes which were tested gave any promise of becoming a successful treatment. The most interesting work was the tests of asphaltums of various grades. In view of the very favorable results which had been reported from California, we hoped that asphaltum would prove to be an excellent treatment.

Our results, however, based on the treatment of hundreds of trees, show the treatment to be unsatisfactory.

Experiments of 1917

During the summer of this year, tests were made of Nicotine Resinate sprayed on the tree trunks as an ovicide and larvicide. Further attention was given to the use of Tocoseal and Tocoseal mixtures. Careful observations were made of the effects on trees and the duration of the coatings. Two new types of mechanical protectors were devised and tested in a preliminary way.

Discussion of Results, 1917

Nicotine Resinate was found to be ineffective as a control for the borers, for infestation was general throughout the treated plots.

Further tests of Tocoseal confirmed the results of our previous year's work. While tocoseal is the most effective asphaltum compound tested it does not give complete protection. Borers were present in twenty percent of the treated trees. Old peach and prune trees were killed or injured by the treatment. Young borers enter the tree above the tocoseal coating.

Preliminary tests of new protectors seemed promising and the work was continued in 1918.

Experiments of 1918

The work of this year included a continuation of the tests of the two types of protectors developed the preceding year and also tests of a newly-developed roofing paper protector. A series of tests was made of a combination of whitewash and spray. Tanglefoot was again applied.

Through the cooperation of Mr. Charles Krogel, we were able to apply several of these tests in his orchard near Roseburg.

Discussion of Results, 1918

Mechanical Protectors. The two types of protectors developed in 1917 gave excellent protection against borers, but their effect upon the trees was such that they were disqualified.

The roofing paper protectors produced less injury to the trees, and gave a degree of protection which marked them as worthy of further investigation.

Whitewash and Spray Combination. These tests were interesting, but inconclusive. The treatment, with certain modifications, was considered worthy of further test.

Tanglefoot as applied gave poor results, and little promise of an economical control for the pest.

Experiments of 1919

The restoration of the Crop Pest Act in the early spring of this year, made possible the prosecution of this work on a much more satisfactory basis than had been possible heretofore. The work during the summer of 1919 was conducted very largely in the orchard district surrounding Roseburg. The junior author made his headquarters in the city of Roseburg. A small insectary was established here, while experiments were conducted in the orchards of the surrounding district. The cooperation of fruit growers in permitting experiments to be conducted in their orchards, greatly facilitated the work. Experiments were located in the orchards of John Busenbark and Sons, Chas. Krogel, Edward Bryant, Mrs. Nettie Bryant, and Arthur Marsh.

The work of the year included a continuation of tests of roofing paper protectors, and of whitewash. A new, and it is hoped, more effective whitewash mixture was developed. Spray mixtures were developed and tested, and a series of colored washes was applied. Preliminary tests were made with fall and winter applications for the destruction of over-

wintering larvae. Life-history studies were made in the Roseburg district, and also at Corvallis and Salem.

Discussion of Results, 1919

Roofing Paper Protectors. Considerable difficulty was experienced in keeping these protectors sealed to the trees, and we doubt if it would be practical to give the necessary care in commercial orchard practice. This, together with the facts that they are probably somewhat injurious to the trees, and, as applied in our tests, are not highly effective, renders this type of protector objectionable.

Whitewash. Results of the whitewash treatments this year were not entirely conclusive. However, the treatment gave a degree of control which we considered promising, and which we regarded sufficiently satisfactory to warrant the application of whitewash on a large scale in commercial orchards.

New Whitewash Mixture. A new wash which we have termed the Fuller's Earth Wash was developed during this season. It was perfected too late in the season to be treated in more than a preliminary way. Its remarkable sticking powers seemed very satisfactory, and it was deemed worthy of further investigation.

Miscible Oil—Sodium Arsenate Sprays. Sprays consisting of a combination of miscible oil and sodium arsenate were applied to the bases of the trees. Two objects were in view: the outer layers of bark would be saturated with this soluble poison, which we hoped would act as a barrier to newly-hatched larvae attempting to enter the tree. By thus saturating the outer layers of bark with a soluble poison, we hoped to kill any young larvae which may have penetrated the bark shortly before the spray was applied.

The results which we obtained were not such as to lead to the immediate recommendation of this as a treatment for the root borer. The treatment seemed sufficiently promising, however, to warrant its continuation during 1920.

Colored Washes were applied to the bases of the trees to determine whether the trees might be "camouflaged," so to speak, and in this way restrain the moths from ovipositing on the tree trunks. Brown, green, orange, blue, red, and yellow washes were used, with little effect upon the moths, although there is slight evidence that the moths were attracted by the red and yellow washes.

Winter Treatments. In the course of our observations on the habits of the root borer, we discovered that during the winter months a considerable proportion of the worms leave their burrows under the bark, and entering the soil, spin silken cells against the tree trunk beneath the soil surface.

With a view of destroying these larvae in their silken cells, and also those which remain in the outer layers of bark, we applied a number of substances about the bases of trees in the State Hospital orchard at Cottage Farm, Salem. These applications included miscible oil, sodium arsenate, nicotine, sulfate, nicotine oleate, and nicotine resinate applied as liquids. Fuller's earth and nicotine sulfate, dust, sulfur, arsenate of lead, and tobacco dust were applied dry. None of the treatments gave satisfactory results. This type of treatment is therefore unsatisfactory unless some more effective larvicide can be found.

Experiments of 1920

During the summer of 1920 intensive work was done in testing whitewashes of different formulas, sprays of sodium arsenate and oil, and the application of lime sulfur and arsenic mixtures. In a minor way, tests of roofing paper protectors were continued. Through the cooperation of Mr. F. H. Zinzer a series of experiments was conducted in the State Hos-

pital Orchard at Salem, and another series was conducted at Roseburg through the cooperation of John Busenbark and Sons.

Discussion of Results, 1920

The results, as here given, are of necessity somewhat incomplete, and a full record of the results of the year's work cannot be made until next spring. We believe, however, that these results indicate fairly well the efficacy of the several treatments.

Miscible Oil—Sodium Arsenate Sprays. The formula was as follows:

Water to make	2 gals.
Sodium arsenate	2 ozs.
Miscible oil No. 1	1 pint

The sodium arsenate was dissolved in a small quantity of water. The miscible oil was diluted by adding a small quantity of water at a time while the mixture was being thoroughly agitated. The sodium arsenate was then added and the solution brought up to two gallons by the addition of water.

This spray was applied to the bases of the trees from the soil surface to a height of approximately eighteen inches. Enough spray was applied to wet the bark thoroughly and to puddle perceptibly about the base of the tree.

Our results show that the average infestation of the trees to which this treatment has been applied is lower than in the untreated check rows. The reduction is not sufficient, however, to constitute a satisfactory control. While our results are as yet preliminary, this treatment does not promise to be an effective means of combating the root borer.

Lime-sulfur—Arsenical Mixtures. A series of tests was applied in the orchard at Cottage Farm, Salem, to determine the effectiveness of a concentrated lime-sulfur-arsenate of lead spray applied to the trunks of the trees at various times during the summer. The mixture was applied by means of a small compressed-air hand sprayer with bordeaux nozzle in exactly the same manner as the miscible oil arsenical mixture.

The formula used was as follows:

Lime-sulfur (28° B)	½ gallon
Arsenate of lead (powder)	¼ pound
Water to make	2 gallons

It is apparent from our results that at best there is little, if any, reduction which can be attributed to the treatment, and we cannot consider this as promising satisfactory control of the root borer.

Tree Washes. During this season rather extensive tests were made of Fuller's Earth Wash, and of Whitewash containing various active elements such as arsenate of lead, nicotine sulfate, etc. These were applied in the State Hospital orchard at Cottage Farm, Salem, and in the orchard of John Busenbark and Sons, Roseburg. In applying all of these washes, the soil was removed from the base of the tree to the depth of about four inches. The trees were allowed to stand thus until next day, when the adhering soil particles were removed from the trunks by means of a stiff brush. The wash was then applied as a paint by means of a whitewash brush, the trunks being coated to the height of fourteen to sixteen inches.

The applications were made at Salem on July 2 and repeated on August 26. At Roseburg the first application was made on June 28, and repeated on August 11.

Whitewash. The formulas used were as follows:

Row A1	Quicklime	8 pounds
	Arsenate of lead (powder)	¼ pound
	Salt	2 pounds
	Glue	¼ pound
	Nicotine sulfate 40%	2 ounces
	Water to make a thick paint	

Row A2 Similar to A1 with the addition of one pound of copper sulfate

Row A3	Quicklime	8 pounds
	Salt	2 pounds
	Glue	¼ pound
	Napthalene (flake)	12 ounces
	Water to make a thick paint	
Row A4	Quicklime	8 pounds
	Arsenate of lead (powder)	¼ pound
	Salt	2 pounds
	Glue	¼ pound
Row A5	Quicklime	8 pounds
	Salt	2 pounds
	Glue	¼ pound
	Nicotine sulfate 40%	2 ounces

Our preliminary results show that in general there was a distinct reduction of infestation in the whitewashed trees, although in some cases this is not much greater than may be accounted for by chance irregularity in distribution of infestation. The addition of copper sulfate to the wash seems to have no beneficial effect. The presence of arsenate of lead seems to have less effect than one might suppose. The plot at Salem in the treatment of which the lead arsenate was omitted, shows a slight increase in infestation over the rows in which this was included.

The rows treated with the wash containing the flake napthalene showed up to best advantage. In ten trees examined at Salem, only two trees were found to be infested, and these harbored a total of only three larvae. The trees at Roseburg showed up even better; in ten trees examined no infestation was found.

Fuller's Earth Wash. The Fuller's earth washes were prepared in a series quite closely parallel with the whitewash series. With one or two exceptions the active elements in the combinations were similar, the only differences between the two series lying in the basic composition of the washes.

The formulas used were as follows:

B1	Fuller's earth	8 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Arsenate of lead	1 pound
	Nicotine sulfate 40%	4 ounces
	Water to form a thick paint	
B2	Similar to wash B1 with the addition of 1 pound of copper sulfate	
B3	Fuller's earth	8 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Napthalene (flake)	12 ounces
	Water to form a thick paint	
B4	Fuller's earth	8 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Derris (powdered)	1 pound
B5	Fuller's earth	8 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Arsenate of lead	1 pound
	Molasses (stock food)	4 pints
B6	Fuller's earth	8 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Nicotine sulfate 40%	4 ounces
	Water to form a thick paint	
B7	Quicklime	5 pounds
	Molasses (stock food)	4 pints
	Glue (granulated)	1¼ pounds
	Arsenate of lead	1 pound
	Nicotine sulfate 40%	4 ounces
	Water to form a thick paint	

It will be noted that wash B7 is similar to B1, except that lime has been substituted for Fuller's earth.

Examination of our preliminary data shows that the washes containing the flake napthalene again gave the most satisfactory results. This

uniformity is especially gratifying, and leads us to hope that this wash may prove to be really valuable in the control of the root borer. Too great optimism should be avoided, however, for more extensive application may reduce the efficacy of the wash, and there is also a possibility that this combination may prove injurious to the trees.

In general, the Fuller's earth washes seem to show some superiority over the whitewashes, although it is difficult to establish this fact with a high degree of certainty upon this incomplete data.

There seems to be an improvement in this wash due to the addition of one pound of copper sulfate. The presence of the arsenate of lead also seems to increase the efficacy of the wash. The substitution of lime for the Fuller's earth in this wash seems to have a detrimental effect.

Heavy Lime Liquid Application. One row in the State Hospital orchard was treated with a heavy lime mixture of the following formula:

Lime	1 pound
Molasses (stock food)	1 pint
Glue (granulated)	1 pound
Sodium arsenate	2 ounces
Water to make two gallons.	

This wash was applied by means of a small hand sprayer with Bordeaux nozzle. The soil was removed from about the trees and the liquid was applied as a solid stream.

Results show that this treatment is unsatisfactory.

Whitewash with Sodium Arsenate. On one row in the State Hospital orchard a wash was applied in which quicklime nad sodium arsenate was substituted for Fuller's earth and lead arsenate respectively. The following formula was used:

Quicklime	5 pounds
Molasses	4 pints
Glue	1 pound
Sodium arsenate	2 ounces
Nicotine sulfate 40%	4 ounces
Water to make a thick paint	

As a result of this treatment there is an apparent reduction of infestation. This reduction, however, is far from sufficient to constitute a control, and the treatment cannot be considered satisfactory.

Roofing Paper Protectors. Roofing paper protectors were applied to twenty trees in Busenbark's orchard at Roseburg during the spring of 1920. A number of the protectors which had been placed on the trees in 1919 were resealed.

Examination of these protectors on October 24, 1920, showed that on the whole they were well sealed, and in good condition in every way. At this time ten of these protectors were removed, the effects of the protectors noted, and the trees examined for borers.

In every case the trunks of the trees beneath the protectors were wet, and there was more or less mold present. In some cases there was considerable gummosis beneath the protectors, but as a rule, this was not excessive. Beyond this there was no noticeable injury to the trees, even where the protectors had remained for two seasons. Two trees were found to be infested, one larva being found in each of the infested trees.

SUMMARY

The Western peach and prune root borer has been a serious pest in Oregon since the earliest days of orcharding in this State.

Including investigations of the closely related Eastern peach tree borer, efforts have been made to control the pest for more than one hundred and fifty years.

Injury is produced by the "worm" or larval form, which tunnels under the bark at the crown of the tree. The cumulative effects of continual attacks season after season are most destructive.

The winter is spent in the larval stage at the crown of the tree. Adults first appear late in June, and continue to emerge and deposit eggs throughout the summer. There is but a single generation in the course of a year.

Natural agencies are important in reducing root borer infestation. These are not sufficient to prevent serious injury to trees in commercial orchards.

There is considerable variation in the susceptibility of stone fruits to attack. They are in order: almond, peach, apricot, prune, and cherry. We have found no varieties of prune immune to attack.

CONTROL RECOMMENDATIONS

WORMING. Digging the borers from their tunnels is the most thoroughly reliable treatment yet established. To accomplish this remove the soil from the bases of the trees and cut out the borers. Use a sharp knife, and make clean cuts. It is well to apply an antiseptic wash such as bordeaux mixture to the wounds before replacing the soil.

The preferable times for worming are the spring months prior to July 1, and the fall months subsequent to September 1.

ASPHALTUM, TANGLEFOOT, ETC., as applications to the bases of the trees are not recommended.

TREE PROTECTORS when properly applied seem to give good results. Because of the labor and difficulty involved, and the danger of stimulating root rots, however, we do not recommend the use of protectors.

WHITEWASH TREATMENTS. In view of the results produced by our recent experimental work as well as the favorable reports from commercial orchardists who have used the whitewash treatment, we believe that growers are warranted in applying this treatment on a large scale. This treatment should be applied in connection with worming.

We suggest the following formula as likely to give favorable results:

Quicklime	8 pounds
Arsenate of lead (powder)	¼ pound
Salt	2 pounds
Glue (flake or granulated)	¼ pound
Nicotine sulfate 40%	2 ounces
Water to make a thick paint	

Remove the soil from the bases of the trees to the depth of three or four inches. Allow the crown to dry and then, with a stiff brush, remove all adhering soil particles from the crown and trunk. Apply the wash by means of a whitewash brush, coating the trunk to the height of fourteen to sixteen inches. Replace the soil about the tree.

The first application should be made in connection with "worming" in the spring. It should be as immediately preceding July 1 as possible.

We believe another application about mid August is advisable for best results.

NAPTHALENE WASHES gave best results in our work of 1920. We do not recommend this treatment, however, until more data can be obtained regarding the effect which this material has upon the trees, as well as the efficacy of the treatment.

These recommendations are not final, and are likely to be changed after further investigation.

IMPROVED SPRAYS AND PRACTICES IN CODLING-MOTH CONTROL

By LEROY CHILDS and A. L. LOVETT

Investigations of horticultural sprays and spray practices have occupied an important place in the experimental projects of the Oregon Experiment Station[10] for the past decade. The value of these investigations is demonstrated by the fact that our growers in the more specialized fruit sections have adopted the most approved spray combinations; employ the most up-to-date spray practices and achieve a remarkably high degree of excellence in orchard pest control.

This discussion is an attempt to correlate our more recent findings as applied to improved codling-moth control. It represents the combined work and investigations of the two authors. Much of the material has appeared in recent Station bulletins, and we have here endeavored to digest the essential features as related to the topic under discussion, codling-moth control.

ARSENATE OF LEAD

Generally speaking, arsenate of lead is the standard poison spray material for use in codling-moth control.

The material is prepared in two forms, as a paste and as a powder. From the standpoint of physical qualities, transportation, ease of preparation for use in the spray tank, immunity from freezing or evaporation, and efficiency in control, the powdered form appears to be the superior type to use.

From the chemical point of view, likewise, two forms of lead arsenate are manufactured; namely, the acid, diplumbic, or lead hydrogen arsenate and the basic, neutral, or triplumbic type. Experiments show that most of the commercial lead arsenates on the market, unless specifically labelled otherwise, are the acid form. The acid lead arsenate has the higher killing efficiency, stays in suspension better, adheres more firmly to the sprayed surface and as a codling-moth control and as a poison application is the advisable form for use on pome fruits, such as the apple and bear.

Physical Properties an Important Factor. In connection with our poison-test experiments to determine the comparative efficiency of the acid and basic lead arsenates it was determined that under laboratory control conditions a dosage of one pound of acid lead arsenate to 400 gallons of solution is an effective killing strength. In our general orchard spray program, this finding to the contrary notwithstanding, the general practice is to use two pounds of the powdered lead arsenate to 100 gallons, or a dosage eight times as strong as the theoretical amount required. Allowing for the natural factors which make it impossible to achieve ideal results under field conditions, the discrepancy yet remains disproportionately great. In an attempt to explain the causes for this discrepancy a plausible premise appeared to be a study of the physical properties of sprays and spraying and their possible improvement. Studies now in progress include investigation of (1) the physical properties of the spray solution and its improvement; (2) the physical properties of the poison spray materials and the standardization of methods for their determination; (3) the improvement of the physical factors in methods of application.

SPREADERS AND SPRAY SOLUTIONS

It is a matter of common experience that when examining a sprayed tree to check on the thoroughness of application one judges largely by

[10] Lovett, A. L. Insecticide Investigations, Ore. Sta. Bul. 169, 1920; Childs, Leroy, Spray Gun versus Rod and Dust in Orchard Pest Control, Ore. Sta. Bul. 171, 1920.

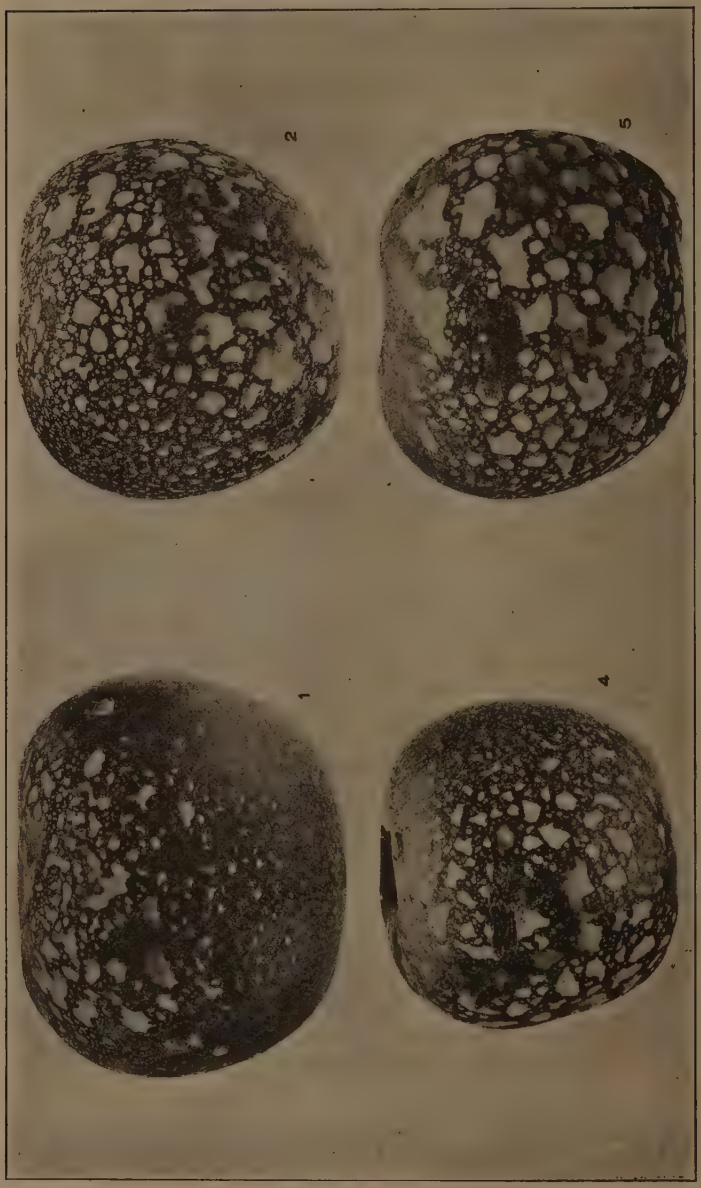


PLATE IV

Appearance of sprayed fruit in commercial tests of physical properties of various leads and spreaders.
(1) Latimer's lead arsenate 4-200 alone. (2) Latimer's lead arsenate 8-200 alone. (4) Rex Nuform 4-200 alone.
(5) Rex Nuform 6-200 alone.

the presence or absence of half circles and blotches of dried arsenate deposited more or less irregularly over the sprayed surface. These blotches are seldom of uniform thickness throughout, tending to a heavier coating along one margin. There are interspaces between the blotches apparently free of poison.

Where the material occurs on the fruit surface in heavy blotches it is more readily removed by rain. Coarse droplets tend to collect and run, carrying with them all or most of the poison material to rest on or drip off the lowest lobe of the fruit. These physical defects would seem to limit the effectiveness of the spray solution.

By improving the physical properties of the spray solution we should increase the effectiveness of the poison dosage. Our conception of an efficient spray solution is one which, as it is applied, allows the droplets so to spread out and join one another that upon drying the arsenate finally rests as an even, regular, inconspicuous covering, affording a perfect and equal protection for every surface.

One of our major endeavors, therefore, has been to improve the physical properties of the poison spray solution by the addition of some substance that would assist in developing this desirable tendency of the droplets to spread and join one another. For convenience we have termed the substances added for this purpose "spreaders."

The Use of Spreaders. The use of a spreader in the poison spray solution accomplishes a number of desirable things. By increasing the wetting and covering powers of the solution it permits us to reduce the amount of arsenic necessary for protection. By permitting a more uniform covering over the surface and increasing the adhesiveness, it affords a better protection from worms. Through the increased wetting and covering powers afforded, less solution is required to cover the trees and a tank of spray will go farther. Finally, allowing the spray to dry as a smooth, even covering over the surface we get an inconspicuous coating of the mature fruit. This does away with the blotchy, conspicuous poison coating so objectionable on the fruit when our apples and pears are entering eastern markets, particularly since there has recently developed a tendency to discriminate against the heavily sprayed western fruit.

The investigation of possible spreaders and their economic value in improving the efficiency of the spray solution under commercial orchard spraying conditions has been under way four years. Many problems in connection with the investigation have not as yet been satisfactorily solved. Of the materials tested as spreaders, cheapness, availability, compatibility, efficiency and ease of preparation considered, casein, miscible oil, glue, and proprietary soaps appear most satisfactory.

Casein. The casein used in the preparation of the spreader is the commercial powdered or granulated casein as derived from milk. The material may be purchased through the local druggist, or the fruit unions may obtain it in quantities for the accommodation of their growers. In preparing it for use, make up a stock material.

STOCK CASEIN SOLUTION.

Casein	20 ounces
Sodium hydroxide	3 ounces
Water	2½ gallons

Add the sodium hydroxide to the water and heat to boiling. While heating, add the casein. Boil for ten minutes. Replace the water lost by evaporation. This forms the stock solution. For use, stir vigorously and remove one quart of the stock solution to add to each 100 gallons of spray.

Where the casein is finely powdered, a more simple method of preparation has been employed successfully:

STOCK CASEIN-LIME MIXTURE.

Casein	4 pounds (or parts by weight)
Hydrated lime	20 pounds (or parts by weight)

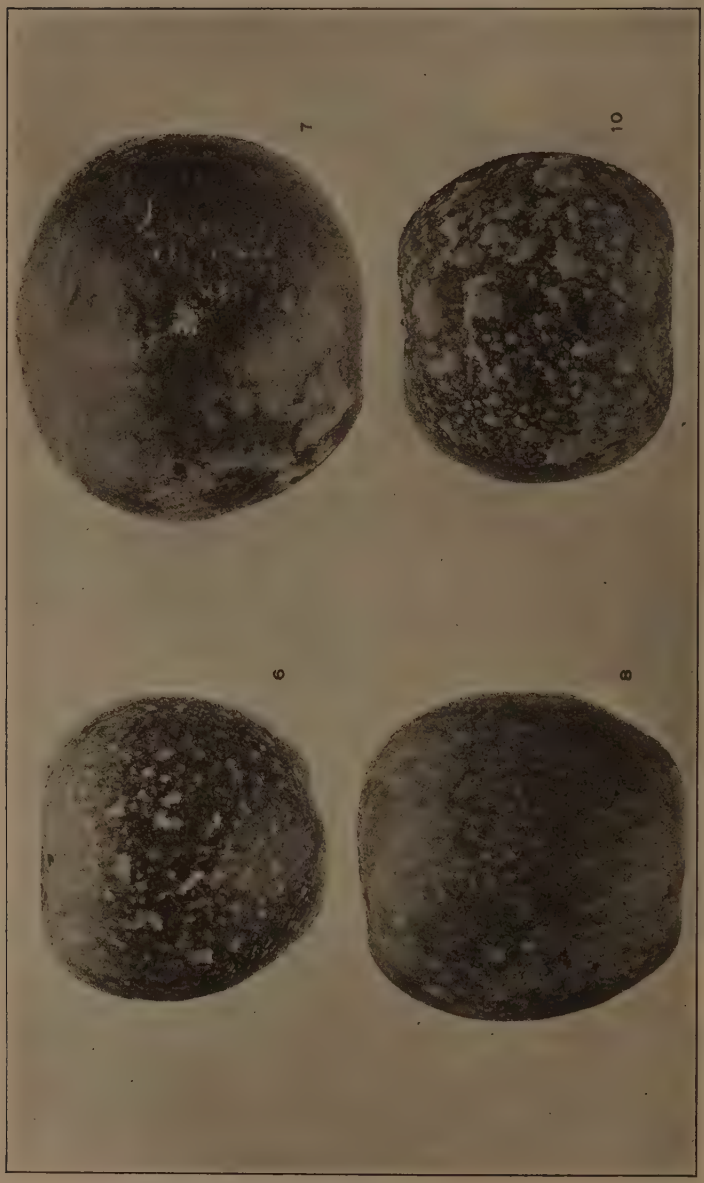


PLATE V

Appearance of sprayed fruit in commercial tests of physical properties of various leads and spreaders. (6) Glidden's lead arsenate 4-200 alone. (7) Glidden's lead arsenate 4-200 plus caseinate spreader. (8) Glidden's lead arsenate 4-200 plus soap bark spreader. (10) Sherwin-Williams calcium arsenate 8-200 plus caseinate spreader.

The materials must be thoroughly mixed. Add the casein slowly to the lime (dry), while stirring vigorously. Pour the mixture from one container to another, repeating the operation until the materials are uniformly mixed.

Use one and one-half pounds of this stock mixture to the 100 gallons of spray. The powder may be added dry directly to the spray tank. Pour the mixture slowly into the filled tank while the agitator is running. Start spraying at once or run the agitator for at least ten minutes to insure a complete solution of the spreader.

Miscible Oil Emulsion. This appears to be one of the most efficient spreaders. The adhesive qualities of the dried material are not equal to casein. The emulsion is easy to prepare, readily obtainable, and not excessive in price. The lighter grades of miscible oil are probably advisable. No tests of the various brands have been made, though theoretically there should be nothing in favor of one brand over another. In our tests we used General Chemical Company's Miscible Oil No. 2.

One gallon of oil is used to each 100 gallons of spray. Do not attempt to pour the oil directly into the spray tank. First thoroughly mix the oil emulsion in the container. Remove the desired amount of oil and add slowly, with vigorous stirring, twice the amount of water. The solution should become a milky white emulsion of uniform consistency throughout and without any evidence of free oil or soapy flakes. The emulsion may then be added to the filled spray tank while the agitator is in motion. The tank of spray should be applied at once.

Glue. Certain grades of glue are proving very good as spreaders. Unfortunately as yet we are uniformed as to the trade names for the more desirable grades. The average glues on the market are variable in their action as spreaders.

One pound of glue to 100 gallons of spray should be used. Weigh out the number of pounds of glue required for the next day's operation; add to an equal number of gallons of water and allow to stand over night. Use one gallon of the stirred solution to 100 gallons of spray.

Soaps have not given a degree of improvement in the efficiency of the spray that would warrant their general adoption at present. There is also a question as to their uniform compatibility under all circumstances of spray combinations and climatic conditions. Because of the apparent success of other investigators, it is suggested that growers who desire to do so may use soap as a spreader, but bear in mind the possible contingency of spray burn.

THE PHYSICAL FACTORS IN APPLICATION

The development of the dusting method in orchard pest control, closely followed by the production of high-powered spray outfits for use with the spray gun, mark a definite epoch in the development of spray practices.

These new practices were introduced at a most opportune time, offering as they did a reduction in the man power required and an increase in the covering capacity of the spray outfit. The labor problem was particularly acute at the time and resulted in a general interest in the possibilities and merits of the system and a fairly general adoption of one or the other system either entirely or in a modified way.

The general interest in the use of these materials and outfits resulted in the launching of an elaborate investigation at the Hood River Station of the comparative efficiency, value, and adaptability of the different practices. These tests have been under way for a four-year period.

Local conditions may in a few cases vary slightly the results as obtained at Hood River, particularly in respect to the dust application. Generally speaking, however, the limiting factors affecting the results in Hood River would appertain to all fruit sections of Western Oregon.

PLATE VI

Applying dust sulfur and arsenate of lead with a power duster. To give an effective coating dust must be applied under absolutely quiet atmospheric conditions. Prevalence of winds and the limited use of dusting method in combating different orchard pests do not make its use advisable in the Northwest.

The Dusting Method. Dusting was first brought into prominence as a means of orchard pest control by experiments in New York.[11]

There was a general desire on the part of Western growers for information relative to the merits of the system, particularly regarding the possibility of a more rapid and a more economical application of spray.

Dust spray experiments were begun in commercial orchards in Hood River in 1916 and have been continued for a four-year period. Numerous types of dust spray outfits and accessories and various dust mixtures have been employed. The dust spray tests have been checked against adjacent blocks sprayed with rods and, since 1917, against the spray gun.

In general in our experimental tests the dusting method gave approximately as effective control of codling-moth and scab as did the spray rod and spray gun. Care was observed at all times to choose periods when no breeze was blowing for the application of dust. In commercial orchards where this factor of wind was not given equal consideration the results were not always satisfactory.

The Dusting Method in Practice. Provided all conditions are right, there is probably no easier and more effective way of coating a tree with an insecticide, such as powdered sulfur and arsenate of lead, than by the use of a power duster. Thrown from the duster with air as the carrier, the fine particles are carried to all portions of the tree. A wonderful coating is given a tree even to its uppermost branches. The upper and under surfaces of the leaves as well as the fruit can be thoroughly coated. The fine hairs on these surfaces hold the minute particles, and it requires much weathering to dislodge them. A breeze, however, makes it almost impossible to reach the top of the tree with the dust and even if this is accomplished, the particles are in such rapid motion that only a very small percentage sticks. The remainder passes on and for the most part is wasted. When the wind is blowing, nothing can be done. When the air is quiet, the particles hover for a long time on a tree (Plate VI) and gradually settle. Air currents destroy the system and applications made under such conditions can only result in failure.

In carrying on the experimental work, it was found necessary to dust very early in the morning and thus avoid air movements, which usually became sufficiently strong by 8 o'clock to prevent thorough work. During the spring months, it is not uncommon for wind to blow in varying degrees continuously for days at a time. Many times the experimental work was delayed for more favorable weather conditions. We are all familiar with the fact that the applications of spray cannot be delayed to any great extent and at the same time accomplish successful results. Several growers have used the dusting method; for the most part, their work has been done regardless of air movement. In 1918, the condition of the fruit in one of these orchards was checked, and 33 percent of the fruit was found damaged by the codling-moth.

The dusting method is also decidedly limited in its general utility. Of our various orchard troubles, it will satisfactorily control scab and codling-moth. Mildew, anthracnose, leaf-roller, and the various scale insects are unaffected by dust applications known at present and must therefore be handled with liquid spray. The use of the duster would then mean duplication of equipment and an overhead charge that the average-sized orchard cannot stand. For these reasons, the duster has but a limited place in Western orchards at the present time.

The Use of the Spray Gun. The first experimental tests of the spray gun in Oregon were made in 1917, beginning with the calyx application. The outfit used was a commercial ten-horse-power outfit. During succeeding seasons the tests have included spray outfits of 3½-horse-power capacity and the use of one, two, and three guns. The gun came rapidly

[11] Reddick and Crosby, Further Experiments in Dusting and Spraying Apples, Cornell Uni. Agri. Exp. Sta. Bul. 354, 1915.

PLATE VII

The "life" and quality of spray thrown from a gun vary directly with the power back of it and pump capacity. The greater the pump reserve the better will be the quality of the spray. Here we have a very finely broken up spray thrown in nearly a direct line for a distance of 25 feet.

into general use in the Valley; nearly all makes were used, and the gun was used, moreover, on about every make and capacity of spray rig. In our experimental blocks the tests were checked against adjacent blocks sprayed with twelve-foot rods and nozzles. Tests were also made using the rods for the calyx application and following in subsequent sprays with the guns.

Variations in results naturally occurred and certain physical factors and personal elements enter in. For the indifferent or careless individual, results generally will be better where rods are employed. In the use of the gun more attention to technique is required to adapt the spray output to the varying distance and conditions. Handling the short, compact gun eight to ten hours per day is not so wearisome as the longer less-adaptable rod.

In the hands of the average spray man and with the proper outfit either the gun or the spray rod will accomplish the desired results in effective control. A choice between the two depends, therefore, upon their comparative workability. Considered from the standpoint of ease of manipulation, compactness, speed in application, and covering capacity, the gun is the general choice with the orchardist.

Limitations in the Use of the Spray Gun. The spray gun cannot be used effectively on a low-capacity spray outfit. As a matter of fact, our modern 3½- and 4-horse-power machines do not possess sufficient capacity and reserve power to produce the ideal type of spray with two guns in operation. These machines will produce a fair spray, but it is too coarse and there is not the driving power back of it necessary to do effective work in the tops of large trees. One gun may be used effectively, however, with the 3½- and 4-horse-power engine.

In practice, we find that the average output of a 3½-horse-power outfit, operating two guns, is about four gallons a minute for each gun. This is average running time, including the shut-off in travelling from one tree to another. This means that, when both guns are in full operation, the output is considerably higher, approaching, if not equaling, the output of the pumps. Spray machines of this horse-power have a rated pump capacity of from eight to ten gallons a minute. When both guns are operating, an examination of the overflow pipe indicates there is little or no fluid passing over. The pressure as indicated on the gauge may be high (250 pounds, perhaps) and still there is not the "life" that is observed in the spray that is thrown from a sprayer of twenty-gallons-a-minute capacity with the pressure gauge reading approximately the same. A large overflow occurs on these high capacity machines when two guns are being operated, and it appears that it is this added reserve, rather than the pressure indicated, which determines the quality of the spray. One gun on a good 3½-horse-power outfit throws a spray very similar to that from the larger machine. In this case, we have about one-half of the pump output passing through the overflow pipe.

It has also been noted that less spray is used per minute on the large outfits than with the smaller machines. This is probably due to the fact that the material is more finely broken up. A surface can be covered just as quickly with the fine particles, perhaps more quickly, than with a coarser spray. The result is that the gun is shut off more of the time and the average output per minute is reduced, resulting in a saving of spray.

Failures in the Use of the Spray Gun. Poor results that have been obtained with the spray gun are not due to the principles involved in the spray application. Unsatisfactory control can be the result of the misuse of three, or perhaps, rather, the combination of three, misused factors. These are poor equipment, poor work, and irregularity of application. Of the three factors, the first mentioned is probably the most important from the standpoint of the use of the gun. The other two factors are contingent upon the first. The spray gun is a useless accessory to a

poor spray outfit; and where operated with small, inferior equipment, it has given a very poor account of itself and will never give good results. Our up-to-date 3½-horse-power sprayers are too small to handle two guns effectively. When equipped with one gun they function very satisfactorily. A machine of this power, in order to throw a spray of the proper quality, must maintain a pressure of at least 275 pounds. In one orchard under observation a machine of this character was used. In order to keep the spray in proper form the outfit was tuned up and pushed to the limit throughout the season. When you begin to force a gas engine and a pump, trouble begins, and the owner of this machine had his share. This condition of affairs existed in many orchards throughout the valley and was typical of no particular make of sprayer. A spray machine, in order to last as long as it should, and at the same time give results, must have a liberal reserve. A machine of ten horsepower is none too powerful. Such spray machines are now coming into more general use and are winning favor.

Equipment, Dilutions, Combinations, and Suggestions. Poor equipment makes effective control difficult. No more spray rods or guns should be used than the outfit will support and still maintain a good reserve without overtaxing the engine or pump. For low-powered rigs decrease the number of rods, and the size of the openings in the discs of the spray nozzle. Aim to get a fine, misty or fog-like spray with some "life" behind it.

Poor application is no longer the rule in our orchards. On the other hand, there are few growers who could not improve their technique. No combination of desirable factors can entirely overcome the handicap of faulty application, though some of them will tend to decrease it. Considering the saving in spray material and the decrease in the amount of worm injury, one is warranted in paying especial attention to this important essential of application.

Timely applications likewise are of paramount importance. Unfortunately, this essential is the most difficult to foretell with unerring exactitude. A knowledge of the essentials of the life-history of the pests, temperature, and climate observations, and finally the counsel of some specialist, where available, will minimize the errors here. That every fruit section should plan eventually to have for its special service a trained specialist to study local problems and advise with the growers on the time of and combinations for each application, is the consensus of opinion of those who have made a study of orchard pests. Each locality has its own variations, impossible for a specialist from a distance to know or take into account. Usually within a fruit section there are great variations, so that much material and labor could be saved that is now needlessly employed, and higher efficiency could be obtained from the necessary applications. The value of the specialist has been repeatedly borne out in those sections where his presence and training are available to the growers.

The spray for all general orchard work and for all codling-moth applications should be of a fog-like or finely-broken, misty type. With plenty of reserve power we obtain a maximum covering with the minimum amount of solution and a minimum amount of drip.

The spray gun functioning properly gives this type of spray. For use on rods the disc type of nozzle is recommended. Pay attention to the size of the aperture in the disc. When the hole becomes worn, replace the old disc with a new one.

A dilution of three pounds of lead arsenate to 200 gallons of solution is considered sufficient for the earlier codling-moth applications in commercial orchards where a spray program is regularly followed and the worm infestation is not high. Where the worm control has been faulty an increase in the poison dosage is advisable, though improved spray

technique is probably of more importance. For the last summer application, observations and experiments indicate the advisability of increasing the poison dosage by one-half, or four and one-half pounds to the 200 gallons. The addition of a spreader is particularly advisable in this application. Aside from the increased efficiency, the smooth, inconspicuous covering afforded on mature fruit is particularly desirable.

The calyx application is important; however, experiments covering a period of years and a variety of conditions do not warrant our attaching undue significance to this application. Conscientious effort to be thorough is desirable in the application of all sprays. The fog-like or misty type of spray for the calyx application has given equal protection with the driving spray.

The Choice of Lead Arsenate. Physical tests now under way at the Oregon Station (see Mr. Robinson's paper on page 89), supplemented with field tests may, when completed, indicate the superiority of one brand of lead over another. Preliminary field spray tests with various brands this year failed to indicate any marked variation in the efficiency of the brands or to show the superiority of any type or class of the powdered lead arsenates in control. Those brands with a spreader incorporated in the commercial material were of equal value with, but not superior to, those brands without a spreader.

The Use of Spreaders. The value and effectiveness of spreaders in the spray solution are in a measure contingent upon faulty or indifferent application. With high-powered outfits, throwing a misty spray and in the hands of a careful manipulator, the value of a spreader is minimized. Where the droplets of spray are coarse, the application faulty or the time of application incorrect; the presence of a spreader in the solution will tend to minimize the deficiencies. The coarse droplets will not run so readily, the spray will spread and afford a better covering and will adhere longer to the sprayed surface.

For the late summer application the use of some material to offset the tendency to a conspicuous, blotchy, spray covering on the mature fruit is very desirable. A spreader, aside from its value in increasing the efficiency of the spray application, does to a remarkable degree achieve this result of a smooth, even, inconspicuous coating of the fruit.

Combination Sprays. A safe rule to follow in combination sprays is, Do not mix the spray materials in a concentrated form unless the instructions specifically advise it. Generally speaking, each material has its own particular function to perform. Safe combinations of several have been perfected to minimize the number of spray applications necessary. Avoid, so far as possible, any reactions between the materials, as usually such reactions tend to weaken the effectiveness of each material.

For example, in mixing lead arsenate and lime-sulfur a minimum reaction with the attendant formation of sludge will result where the materials are combined in dilute form. Add the lime-sulfur to the filling tank. When the tank is nearly full, start the engine and while the agitator is in motion add the arsenate slowly. Powdered arsenate may be added directly to the spray solution. For best results have the agitator in motion and add the material slowly.

Calcium arsenates, while highly efficient as a poison spray, are unsafe for orchard use unless an excess of lime is present. There is probably no reason at present for abandoning the lead arsenate in favor of the calcium arsenate.

Magnesium arsenate in two seasons' tests has not shown the qualities that would recommend its general adoption for orchard spray purposes.

THE FRUIT TREE LEAF-ROLLER—REPORT ON PROGRESS OF INVESTIGATIONS

By B. B. Fulton

For many years the fruit tree leaf-roller has been known as a common insect throughout the United States. It first developed a reputation as a destructive pest of prime importance in the state of Colorado in 1891. The first serious outbreak there was confined to northern Colorado and lasted for three or four years. Later the insect developed in destructive numbers in other districts in the state. In all cases the agents of natural control reduced the numbers to relative unimportance after the outbreak had run a period of years. The leaf-roller has had a similar history in some other states, including Missouri, California, New Mexico, New York, and the province of Ontario, Canada.

In Oregon the leaf-roller first appeared in destructive numbers in the Hood River Valley about 1912 or 1913, and within a few years became a pest that rivaled the codling-moth in importance. Although the last year has shown a slight decrease in its numbers in the seriously affected districts, it still remains one of our most injurious insects. In parts of Washington it has recently become even more destructive than in Oregon.

Wherever it has developed as a pest its history has been one of rapid increase in numbers from the ranks of the relatively uninjurious insects, and after a period of years, the insect is reduced to its former status. No one should infer from this that active control measures are unnecessary or unprofitable, for the result of some outbreaks has been a complete defoliation of the trees, destroying the entire crop of that season and the crop of the succeeding season by preventing the formation of fruit buds. It is worth while to curb the pest's activity even if it is necessary for only a few years.

In states where the leaf-roller has been destructive in the past, experiments have been conducted for its control. Attempts have been made to kill the insects by means of arsenical sprays, but in no case has this method resulted in more than partial control. Another line of investigation has been the use of contact sprays applied to the trees during the dormant period for the purpose of killing the eggs. This line of endeavor has been attended by a certain degree of success, but the results have been conflicting. The same material at the same dilution has given good control at certain times under some conditions and poor control at other times, under what appear to be similar conditions. The use of certain oil sprays can be recommended and will always give a fair measure of control; still there is much room for further effort toward more uniformly good results.

DISTRIBUTION

The fruit-tree leaf-roller is known to occur throughout the United States wherever its common food plants grow. It has been recorded from Maine and Georgia on the Atlantic, to British Columbia and California on the Pacific, and from Ontario to Texas.

In Oregon it is generally distributed over the Willamette Valley and along the Columbia Valley. It is a serious pest at present only in the Hood River Valley and in a small area near Imbler in the Grande Ronde Valley.

As the name implies, the fruit-tree leaf-roller is a general feeder, but its preferred food plant is the apple. It is also very common on the cherry, plum, prune, and pear, but it rarely attacks peach trees. When the leaf-roller becomes exceedingly abundant in a locality it has been known to breed to a limited extent on a great variety of plants, including the common small fruits and berries and a number of shade trees.

A closely related species, which in the immature stages is almost indistinguishable from the fruit-tree leaf-roller usually occurs with it. This is known as the oblique-banded leaf-roller. It has never been known to become a serious pest itself. The range of the oblique-banded leaf-roller may be as extensive as the other species, but it has received much less attention in entomological literature. In Oregon, so far as known, it is distributed over the same territory as the fruit-tree leaf-roller.

LIFE-HISTORY AND HABITS

The Egg. The fruit-tree leaf-roller spends more than nine months of its life as an egg attached to the bark of the tree. The eggs are deposited in oval masses from one-eighth to nearly one-fourth of an inch long, made up of from ten to eighty eggs, averaging about forty or fifty.

The individual eggs are rather flattened and overlap each other like the scales on a fish. A substance secreted by the moth, at the time of oviposition, hardens and forms a coating which partially obscures the composite character of the egg cluster.

When first deposited the egg masses are greenish, later turning brown, and are not easily observed. After passing the winter on the tree, most of them retain their brown color, but others become pale brown or even whitish. Some of the clusters seem to dry out, during certain years at least, and part or all of the eggs in these clusters fail to hatch even when not touched by a spray. Hatched egg masses generally acquire a bleached whitish color and may remain on the trees through several seasons.

No part of the tree can be said to be free from eggs, although the majority of them are on branches from one-half to two inches in diameter. They may be found on the trunk and main branches and are quite plentiful even on the small terminal twigs, a place which is easily missed when spraying. There is a tendency on the part of the moths to place the eggs at the base of a spur or branch or alongside of some previously deposited egg mass. Clusters of four or five masses partly over-lapping are fairly common. Often the egg masses of two or three seasons are grouped together.

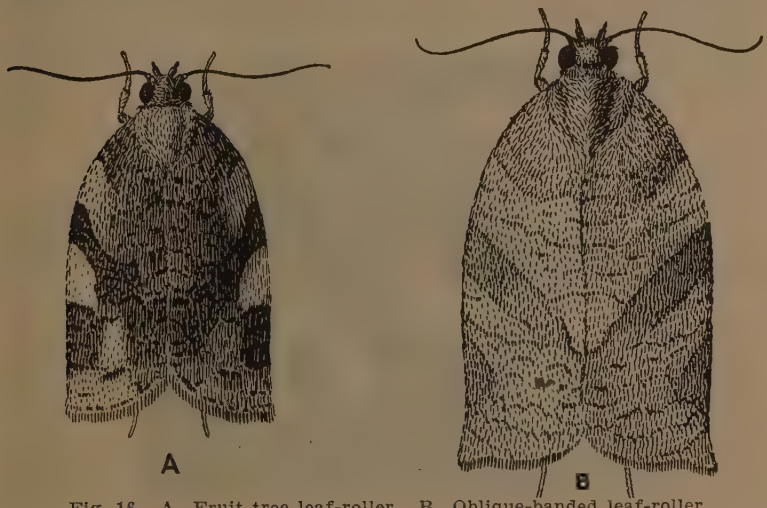


Fig. 16. A. Fruit tree leaf-roller. B. Oblique-banded leaf-roller.

Hatching. The eggs began hatching in the Imbler district in 1920 at the time the trees were in what we call the cluster bud stage, and hatching was not entirely completed until the blossoms showed pink on the majority of trees. The young caterpillar within the egg chews an oval or roughly semi-circular hole through the upper side of the egg and protective coating, through which it crawls to liberty. The process of chewing the hole requires over an hour for completion; those observed took that long after the hole was already of good size. If a spray could be devised that would leave a hardened deposit over the egg mass it might be of value in preventing the hatching.

Habits of the Young Larvae. The newly-hatched leaf-roller is pale yellow with a shiny black head. On leaving the egg it crawls away to explore, and investigates all hollows in the leaves or floral parts, seeking one that is sufficiently enclosed to suit its needs. It then proceeds to spin a silken web further to confine the space, leaving only enough of an outlet to satisfy its present needs for food. The extreme woolliness of many of the growing parts of apple bud, makes feeding on these parts difficult for so delicate a larva, and it is perhaps for this reason that so many of the young leaf-rollers find their way to the blossoms before establishing a web. At any rate the great majority pass the first few stages of their existence within the blossoms. The choice location is beneath the circle of stamens which they web together. Here they feed upon the calyx cup and parts of the stamens and pistils, and may injure or destroy these vital parts before the blossom is fertilized. They also web the petals together and feed upon them, so that many of the blossoms are unable to open when they otherwise would.

Habits of the Older Larvae. After the larvae have molted their skin two or three times, they are about half grown, and of a green color with a black head and thoracic shield. They feed on the leaves more extensively, and keep themselves entirely concealed, either by fastening two or more leaves together and living between them or by rolling up one side of a leaf and feeding within the cavity thus formed. All exposed places are covered with sheets of fine silken web, except that at either end of the nest avenues for feeding or escape are left open. When there is room on a tree for a choice of food, the young terminal leaves and the fruit spurs are attacked first. Large, irregular cavities are chewed in

Fig. 17. Fruit tree leaf-roller, showing larvae and work.

the sides of the fruit, to which a leaf is fastened to form the customary protection. Many of the injured apples fall and those which remain become distorted and scarred.

When the larvae are disturbed sufficiently they wriggle backward out of the nest and drop, but remain suspended by a web spun from the mouth. After hanging for a time they laboriously climb back up to the leaf. This course of action is adopted when attacked by a parasitic insect. If the larvae drop to the ground and land in the sunlight, their lot is a hard one. On cultivated ground they succumb after a few minutes exposure to sunlight. If they alight in the shade they crawl toward the trunk of the tree. In this movement they are probably directed by the sense of sight, for they crawl toward any large, dark object.

Fig. 18. Leaf-roller eggs, upper two unhatched; lower two hatched.

The full-grown leaf-roller caterpillars are about one inch in length. During an average season this size is attained after about one month from the time of hatching.

Pupa. The next step in the life-history is the transformation to a dark brown pupa. The pupa is fastened by a web within a rolled leaf and is entirely concealed. After a period of about two weeks, depending on the temperature, the pupa works its way out to the edge of the nest, by the aid of backward-pointing spines along the abdominal segments. The moth emerges, leaving the empty pupa case fastened to the leaf.

Adult. The moths usually appear from the middle to the latter part of June in the Hood River Valley, and from the first to the middle of July in the Grand Ronde Valley. When at rest the wings are held roof-like over the abdomen, with the inner edges of the fire wings meeting and the hind wings entirely concealed. The males are the smaller, but both sexes vary greatly in size. The length in the normal position ranges from one-third inch (8 mm.) to one-half inch (12 mm.). The typical color is a reddish brown with dark brown and straw-colored markings, but in this also there is considerable variation. Some are entirely pale yellowish or straw-colored and others are entirely brown except for a pale blotch on the outer or costal margin of the wings about half way from the base. In some the ground color is straw-colored, while the markings are dark brown.

THE OBLIQUE-BANDED LEAF-ROLLER

This species occurs, so far as known, in all parts of the State where the fruit-tree leaf-roller is found. The larvae are practically identical in appearance, but the moth is a little larger and has a less patchy appearance. The color is a rather light brown with slightly darker wing bands, narrowly edged with a still darker shade. The colors are also less variable than in the other species.

The life-history in Oregon appears to be the same as that worked out for the same insect in Nova Scotia, where it has only one brood a year, and passes the winter as a young larva. In New York state the writer has reared moths of this species from larvae collected late in the summer, which would seem to indicate that in that locality it has two broods a year. In Oregon the moths appear with the other species or possibly a little earlier and deposit eggs on the leaves. The egg masses are flat, broadly oval, and about one-third of an inch (8 to 10 mm.) long. When first deposited the eggs are pale green, and after hatching are silvery white. The masses have many more eggs than those of the fruit-tree leaf-

roller and lack the thick coating covering the whole. In general appearance they are like a patch of tiny fish scales.

The eggs hatch in late June or July and the young larvae construct tunnels of web on the undersides of the leaves and feed within these protections. Those hatched in the laboratory were placed on apple twigs bearing leaves, on which they fed for a time, but while still small they constructed silken tubes in the crotches of the twigs and remained within them. They are still alive at present writing and will probably survive the winter.

At Imbler many small larvae were found in the spring (1920) in similar hibernacula in crevices in the bark or under dead leaves fastened to the bark. No live ones could be found, however, a result possibly due to the severe winter.

PARASITIC AND PREDACEOUS ENEMIES

Were it not for the heavy toll taken by the natural enemies of the leaf-roller, trees would be defoliated where now they are only severely injured. Seven different species of parasitic insects have been bred from leaf-roller larvae collected at Hood River and Imbler. The larva of the parasite feeds and grows within the body of the living caterpillar, which it finally destroys. No figures can be given on the percentage of leaf-rollers thus killed, but during the time the insect has been under observation in Oregon natural control has not been effective in reducing the outbreak below the danger point. Further study along this line might show that the introduction of other species of parasites would be a profitable undertaking.

A predaceous insect which may account for the death of a good many caterpillars has been found on trees infested with leaf-roller. This is a flattened, shield-shaped insect known as a soldier bug. It is armed with a long beak with which it punctures the worms and sucks out their body juices.

RESULTS OF SPRAYING AT IMBLER IN 1919

The results of the oil spraying experiments for leaf-roller eggs in the spring of 1919 were somewhat conflicting. The writer did not arrive on the ground until after the sprays had been applied and the eggs had hatched. By counting fresh egg masses that had been killed or had hatched, some idea of the amount of control was obtained. The data are faulty because it is not possible to determine exactly whether a hatched egg mass is a recent one or one of the preceding year.

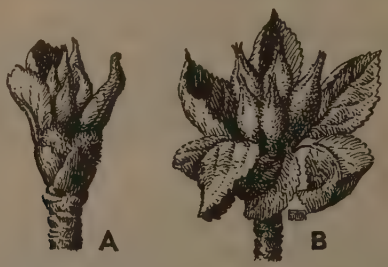


Fig. 19. Miscible oil spraying is safe until after buds pass condition shown in A. Leaf-roller eggs hatch during cluster-bud stage (B)

The growers did not receive their oil until rather late. The buds were well out when the first spray was applied, and there is a possibility

that some eggs may have hatched before the last sprays were put on. The results from four orchards sprayed in the first half of the spraying period, showed 472 dead egg masses and 168 hatched egg masses, or 73.7% control. Four orchards sprayed late gave a count of 381 dead egg masses and 219 hatched, or 63.5% control. Counts made in unsprayed plots showed no unhatched egg masses out of 200 examined.

Some experiments were tried to show the value of nicotine for killing larvae at the time of the calyx spray. One day after the application was made, fruit spurs were examined and the dead and living larvae counted in the blossoms and on the leaves. The results of the experiment showed that nicotine killed a rather high percentage of young larvae on the leaves, but only a small part of those in the blossoms. The total control was poor because the majority of larvae were in the blossoms at the time. The use of nicotine in the calyx spray for control of leaf-rollers cannot be recommended.

RESULTS OF SPRAYING EXPERIMENTS AT IMBLER IN 1920

During the spring of 1920 all orchards in the Imbler district infested with leaf-roller were sprayed with oil. The spraying extended over a period of about two weeks, but was finished well before the time of hatching. First applications were made when the buds were beginning to show the green tip and the last were made when the cluster buds were appearing on the most advanced trees. No serious burning resulted from the use of the oil.

Several kinds of oil sprays were tried in small plots. Soon after each spray was applied a number of the egg masses that had been well covered with spray were tagged so that the same clusters could be examined after hatching had taken place. Care was taken to mark only living egg masses and this point was tested further when the counts of hatched eggs were made. Unsprayed eggs for a check were found on some cherry trees and on a few terminal apple branches that were missed by the spray.

The data obtained from the experiments show that the control was far from perfect in most of the sprayed plots. The average hatch in a few of the plots was higher than for the checks. This undoubtedly means a poor control, but it is entirely possible that if more egg masses had been marked for checks the average would have been much higher. A good many of the egg masses failed to hatch well for some unexplainable reason, possibly the excessively cold winter or the extreme dryness of the preceding summer. Evidently more of these defective egg masses were included among the checks than in some of the sprayed plots.

The best control was obtained in two plots sprayed with miscible oil. In one of these, sprayed April 22 with twelve gallons of oil to the hundred, the hatching was practically nil. In the other case, where eight gallons of oil to the hundred was applied April 27 when the buds were already showing the clusters of blossom buds, the control was 100%. In one plot containing only a few trees, Fuller's earth was added at the rate of five pounds to twenty-five gallons of the oil spray (8 to 100), with the idea of giving a body to the spray so as to leave a heavier coating on the trees. None of the eggs marked in this plot hatched, but since only twelve fresh clusters were found within reach of the ground the test was not conclusive.

In two of the plots, a rain came several hours after the spray was applied. These show poorer results than the same material used at other times. Another plot that was rained on two days later does not show this effect.

In the final summing up it may be said that further research is needed along the line of determining the factors that lead to successful control

by the use of miscible oil sprays. In so doing it is hoped that spraying materials and methods may be worked out that will leave the destruction of the leaf-roller no longer a matter of doubt.

RECOMMENDATIONS

So far as known, the treatment that will give the most successful control is a spray of a heavy miscible oil, eight gallons to the hundred, applied after the buds show green at the tip and before the blossom cluster buds begin to spread apart. Advantage should be taken of any period of fair weather during this interval; for it is important that the spray should remain on the trees a few days before being washed by a rain. Care should be taken that all parts of the tree are sprayed and on all sides.

CHEMICAL AND PHYSICAL PROPERTIES OF THE ARSENATES OF LEAD

By R. H. Robinson

CHEMICAL PROPERTIES

Since the time that arsenicals have been employed as an insecticide in the control of the codling-moth, chemical investigations have been carried on in order to learn definitely regarding the composition of the various arsenates of lead and to choose those forms which will be most efficient. A desirable commercial product must be high in total arsenic for optimum killing efficiency, low in water soluble arsenic in order that foliage burn will not occur, and free from foreign impurities. Investigations to this end have been successful, and two forms of lead arsenate are now on the market; namely, the acid or hydrogen arsenate and the neutral or basic arsenate. It has been found by experimentation that the killing efficiency of the former is superior to the latter and consequently more than 95 percent of the lead arsenate on the market is the acid arsenate form.

During the past several years chemical analyses of samples submitted to the Chemistry department of the Experiment Station, show that manufacturers are producing a very high-grade product, free from impurities and other ingredients that might prove harmful. Consequently no danger need be anticipated from the use of any brand of lead arsenate now on the market. In order to show the composition of the various brands of lead arsenate, representative samples were collected and analyzed. Table X gives the results obtained.

TABLE X. ANALYSES OF COMMERCIAL BRANDS OF LEAD ARSENATE

Brand	Total PhO	Total As_2O_5	Water soluble As_2O_5
	%	%	
1. Rex	63.14	28.57	Trace
2. Latimer	64.41	31.27	Trace
3. Corona	63.96	.....	Trace
4. Glidden	65.71	30.46	Trace
5. Grasselli	64.41	31.84	Trace
6. Sherwin-Williams	63.19	31.64	Trace
7. General Chemical Company	63.74	31.04	Trace
8. Dow	64.86	30.75	Trace
9. Electro	64.14	32.19	Trace
10. Devoe-Raynolds	63.82	31.80	Trace
11. Riches-Piver	63.74	32.94	Trace
12. Ortho	63.87	32.36	Trace

The composition of the arsenates as reported in the table indicates only a slight variation in the different brands. Furthermore, this variation is not due to the presence of impurities. All the samples reported are the acid lead arsenate form, containing small amounts of the neutral lead arsenate, which accounts mainly for the slight variation in composition of the different brands. Attention is called to the low water soluble arsenic content of all samples. This further emphasizes the high degree of purity of the commercial brands that are now found on the market. We can conclude, therefore, from these and numerous other analyses made by the Chemistry department that from a chemical composition standpoint all brands of lead arsenate are safe to use, and equally efficient results may be expected from any of them.

PHYSICAL PROPERTIES

Since most brands of lead arsenate now on the market may be judged practically the same from a chemical composition standpoint, any apparent differences may be ascribed to their physical properties. A high-grade

arsenical that will give best control of insect pests should not only contain a certain percentage of arsenic, but should also be in a very fine state of subdivision in order that it will remain suspended in water for a reasonable length of time and when sprayed will form a thin, uniform film of the poison on the surface to be covered. Superficial examination of the various commercial brands indicates that they differ widely in their physical properties. Some appear finely ground, fluffy, and bulky, while others are coarse-grained and compact. Again we find some brands that contain a fraction of a percent of an organic substance that tends to hold the arsenate suspended in water for a long period of time. For the sake of convenience, we will call these substances "spreaders," since it is claimed by the manufacturers that better spreading of the arsenical is obtained with this material added. The efficiency of the spray material is no doubt enhanced by the addition of a spreader, providing such spreader causes the drops of spray to flatten out and spread over a greater area.

Superficial examinations and observations of spraying tests indicate possible differences in the physical properties of various brands of lead arsenate on the market. In order to ascertain whether these differences are of such magnitude that one brand may be classified as superior to another, a study of the physical properties of twelve brands has been made.

Settling Tests

The length of time an arsenical will remain suspended in water is an indication to a limited extent of the size of the integral particles. The larger granules will settle immediately, while the fine, flour-like particles will remain suspended in water for a longer period of time. A lead arsenate containing fine, flour-like particles is, of course, more desirable. In order to judge clearly between brands, distinction must be made between a sample that consists mainly of very fine particles and a sample that contains a high percentage of coarse particles, together with a small amount of very fine particles that will remain in suspension a long time and render invisible the larger particles that settle immediately.

To show the relative amounts of fine particles of the various commercial brands of lead arsenates that remain in suspension during a definite length of time, glass cylinders containing 100 c.c. of water and one gram of the lead arsenate were prepared. These cylinders were then agitated thoroughly and photographs were taken after allowing the contents to settle five minutes and again after two hours. Since there was little difference between the amounts that had settled in five minutes and two hours only one photograph is reproduced in Plate VIII, which shows the amounts that settle in the time specified.

It will be observed from the photograph that some brands remain in suspension for a long period of time, while others settle almost immediately. Chemical tests show that those cylinders where the arsenates remain in suspension for a long period of time contain an organic substance or "spreader" that has been added by the manufacturers. In the series shown above, three different brands, numbers 8, 9, and 10, contain these spreaders. Reference will be made to numbers 13 and 14 later. The chemical tests show, furthermore, that the substance added as a spreader is harmless, and since it seems to penetrate the lead arsenate particles and cause them to subdivide into smaller sizes instead of clinging together in clusters that settle rapidly, it no doubt benefits the physical properties from that standpoint. Conclusive data have not yet been obtained showing whether or not the spreading or adhering properties have been materially improved. It was found that any of the brands that settle rapidly can be made to remain in suspension for a much longer period of time by thoroughly shaking occasionally during the day for several days. Apparently, the particles are subdivided into smaller sizes by this treatment and will then remain in suspension for a longer time.

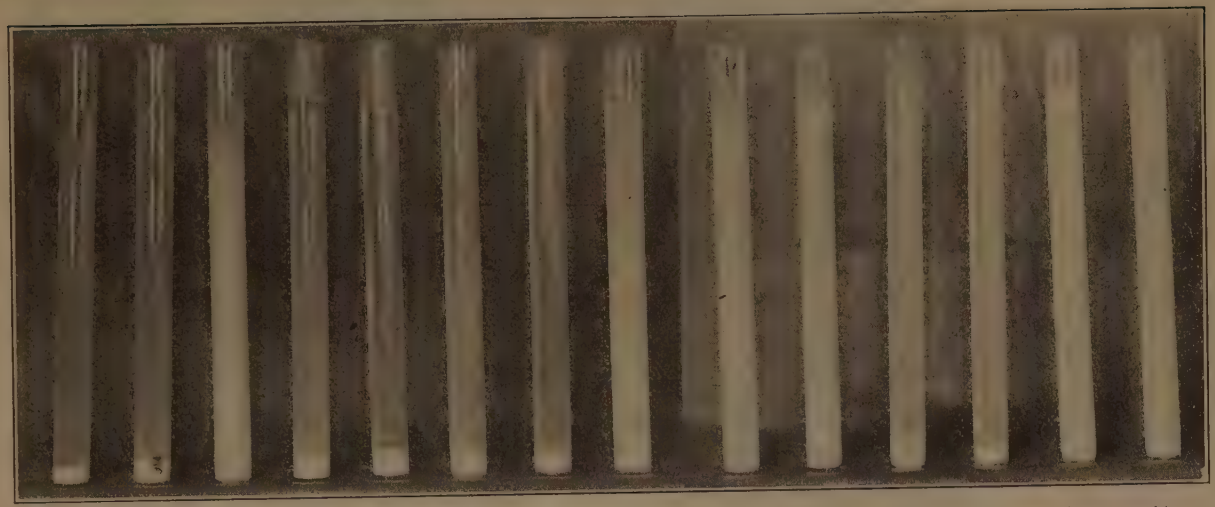


PLATE VIII

SETTLING TESTS OF DIFFERENT COMMERCIAL LEAD ARSENATES.

Brands: (1) Grasselli, (2) Sherwin-Williams, (3) General Chemical Co., (4) Dow, (5) Electro, (6) Devoe & Raynolds, (7) Riches-Piver, (8) Ortho, (9) Rex, (10) Latimer, (11) Corona, (12) Glidden, (13) Corona plus Sugar, (14) Glidden plus Sugar.

The photographs do not show particular points that are distinctive of each brand. Close examination during the settling process warrants the following remarks regarding the samples under observation: Both the Rex and the Latimer brands, which contain "spreaders," held the particles in suspension, but the former had a much higher percentage of large particles that settled in a short time. The Latimer brand also contained an appreciable amount of the larger granules. Corona brand was very uniform and finely subdivided; none of the larger particles that most of the other brands plainly showed could be detected, and it is possible that if further subdivision were brought about by the aid of a spreader, this brand would be superior to any other from the standpoint under consideration. Glidden brand contained a very high percentage of coarse sand-like granules, but the remainder seemed especially finely divided. Grasselli brand was about the same as Glidden, but contained fewer coarse particles. Sherwin-Williams brand was fairly uniform, occupied a large volume after settling, and contained a few coarse granular particles General Chemical Company's brand apparently contained a high percentage of very fine particles and a few coarse granules. Dow brand also contained a few very granular particles, but was otherwise good. Electro brand was uniform in size of particles and contained no coarse granules, but was not as good as Corona. Devoe and Raynolds brand and Riches-Piver brand were fair except for a few of the coarse particles. Ortho brand contained a spreader and apparently was a fair grade sample.

The photographs show that one brand of lead arsenate will remain in suspension longer than another, but only the approximate amount can be judged. To show the actual amounts that remain in suspension after five minutes the cylinders used in the settling tests were shaken thoroughly and allowed to stand five minutes. The particles that remained in suspension were siphoned off with the supernatant water, evaporated to dryness, and weighed. Since one gram of each brand was used in the settling tests the amount of large particles that settled was calculated by difference. Table XI gives the percentage of fine particles that remained in suspension and the amount that settled.

TABLE XI. THE RELATIVE AMOUNTS OF LEAD ARSENATE THAT SETTLED AND REMAINED SUSPENDED IN WATER AFTER STANDING FIVE MINUTES

	Brand	Particles in suspension	Particles settled
		%	%
1.	Rex	76.60	23.40
2.	Latimer	90.75	9.25
3.	Corona	3.63	96.37
4.	Glidden	8.96	92.04
5.	Grasselli	2.85	97.15
6.	Sherwin-Williams	1.84	98.16
7.	General Chemical Co.	12.84	87.16
8.	Dow	4.85	95.15
9.	Electro	2.50	97.50
10.	Devoe & Raynolds	1.78	98.22
11.	Riches-Piver	2.64	97.36
12.	Ortho (California Spray Chem. Co.)	71.62	28.38

The results given in the table indicate a perceptible difference in the various brands of lead arsenate. Since only the very fine particles remain in suspension, the table reflects to a certain extent the relative amounts of large and small particles. The three brands containing a spreader naturally show the highest amounts that remain in suspension. Among the other brands the General Chemical Co. brand, especially, contained a high percentage of small particles that remained in suspension for the length of time specified. It is interesting to note that Glidden brand, which showed in the settling tests the presence of a larger amount of coarse, granular particles than any other brand, also contained a high

percentage of the smaller particles that remained in suspension. No wide differences were observed in the other brands.

In order to gain further information regarding the size of the particles of different brands of lead arsenate, micro-photographs were taken of a drop of the spray that had been transferred to a slide and dried at room temperature. All slides were prepared in a similar manner by shaking 100 c.c. of water containing one gram of the lead arsenate and removing a small drop by means of a capillary glass tube. The drop was transferred to a clean slide and dried at room temperature. Micro-photographs magnifying about thirty diameters were then taken of the prepared slide. The white sections are the lead arsenate particles.

Fig. 20. Micro-Photographs of Particles of Different Commercial Lead Arsenates. (A) Latimer Brand. (B) Rex Brand. (C) Grasselli Brand. (D) Corona Brand.

Photographs taken of all the different brands are not reproduced here on account of the great similarity between many of them. It will

be observed from the prints that the main contrasting differences were between those brands containing the "spreaders," and those without the "spreaders." In general, all of the brands containing the spreaders were similar to A and B in Figure 20, while those without spreaders were similar to C and D. Apparently those brands containing spreaders are superior to the others, since the particles seem more atomic, uniform in size, and the particles adhere to each other, forming an ideal film. Those brands without spreaders, on the other hand, seem to be grouped in clusters and somewhat irregular, leaving interstices between the groups of particles. It is probable that the latter would wash off quickly by the continued action of rain and heavy dew, while those brands containing spreaders would offer less resistance and consequently tend to adhere longer to the surface covered.

The foregoing work indicates that the presence of a so-called "spreader" improves the physical properties of the arsenates of lead by causing further subdivision of the particles when agitated in water. It is questionable, however, whether this effect would be a practical improvement, if the substance used does not also enhance its spreading properties. To learn more definitely regarding those chemicals that might act favorably as spreaders, several classes of substances were compared by observing the relative lengths of time a certain concentration would keep arsenate of lead in suspension. It was found that many substances would assist in holding an arsenical in suspension to a greater or less degree, but many of them do not increase the spreading properties. Among the substances that assist in holding lead arsenate in suspension are calcium caseinate, soluble gums, glue, certain of the sugars, soluble starch, sodium silicate, and soap solutions. Some of these materials, however, do not have a beneficial effect as spreaders and, even though the particles do remain in suspension for a longer period of time by the addition of such a substance, this alone would not warrant its use. The value of several substances as spreaders is reported by A. L. Lovett in Oregon Station Bulletin 169.

Attention is called to numbers 13 and 14 in Plate VIII. These two cylinders are the same as numbers 11 and 12 except that a small amount of sugar (glucose) has been added. The sugar holds the fine particles in suspension for a long time but, according to the results obtained in Bulletin 169, does not act as a spreader. No benefit, therefore, would be derived from its use. Likewise, commercial brands which contain a substance that does not improve its spreading or adhering properties are no better than other brands without added spreaders.

SUMMARY.

From a chemical standpoint all commercial brands of lead arsenate are practically the same in chemical composition, safe to use and probably equally efficient.

The study thus far completed of the physical properties of commercial brands of lead arsenate indicates that there is an appreciable difference in the size of particles, the proportion of large and small particles, and their suspension qualities.

The presence of a so-called "spreader" apparently causes further subdivision of clusters of arsenical particles and tends to hold them in suspension for a long period of time. An efficient spreader should also cause the drops to flatten out and spread over a large area. Field spraying tests only will show whether those brands which contain spreaders are more efficient than others.

THE PEAR-THRIPS[12]

(Taeniothrips inconsequens Uzel.*)*

By A. L. Lovett

The pear-thrips appeared in Oregon in destructive numbers for the first time in 1919. The most serious injury was on prunes in the Liberty district, south of Salem, in Marion county. Outbreaks of lesser severity occurred in adjacent fruit sections, including northern Linn and eastern Polk counties. All varieties of fruit trees were attacked.

Talks with some of the growers indicate that this injury in a milder form had probably occurred on the older trees for at least two years previous. It is reasonable to assume the pear-thrips had been introduced in this district some time prior to 1917.

THE INJURY.

Three types of injury due to pear-thrips occur. In order of their importance they are: first, the feeding of the adults; second, the feeding of the larvae; and third, the deposition of eggs by the adults in the plant tissues.

The period of activity of the thrips is confined to a relatively brief period in the spring. The adult thrips begin the attack by feeding on the unfolding blossom buds, continuing their injury until about the time the petals fall. In addition to their feeding injury they deposit eggs in the leaf surfaces, fruit stems, and newly-formed fruit. The immature thrips feed in the calyxes and on the forming fruit and foliage until early June.

While all varieties of fruit are attacked, apparently those in which the fruit buds are developed in a cluster, as the pear, prune, apple, and cherry, are more subject to serious injury than those in which the buds are produced singly as in the peach. Undoubtedly, too, certain fruits, such as the prune and pear, lend themselves to serious injury because

[12]For a more complete discussion of the pear-thrips see U. S. Dept. of Agric. Bulletin 173, Life History and Habits of the Pear Thrips in California. This bulletin may be obtained from the Superintendent of Documents, price 15c.

Fig. 21. Appearance of blighted pear buds injured by pear-thrips.

the most susceptible stage of development of the blossom cluster is coordinated with the period of greatest activity of the thrips.

In a heavily-infested prune orchard the opening blossoms are blighted to such a degree as to give the appearance of having been scorched by fire. It is no uncommon thing to find less than two dozen unblighted blossoms on the tree, these latter dropping from the devitalizing effect of egg deposition in the fruit stems. Pears suffer to an equal degree, though in the infested area in Oregon this has not been the rule. Comparatively few commercial pear orchards are within the infested area and apparently the prune has proved the more attractive host to date.

SUSCEPTIBILITY TO INJURY

The Pear. Of the pome fruits, the pear is most seriously injured. The adult thrips emerge from the soil in numbers to attack the pear just as the blossom cluster buds are breaking. They work their way within the cluster and attack the tender individual buds. The feeding scars begin to bleed sap, and, where the infestation is heavy, the buds become shriveled, growth ceases, and the tree assumes the blighted or "scorched" appearance characteristic of pear-thrips injury. The wounds in the tissue permit the entrance of blue molds and the few fruits which escape destruction by the thrips are likely to succumb to this attack. Fruits which do develop to maturity on thrips-infested trees frequently are short-stemmed, scabby, and malformed.

Egg deposition in the fruit stems is responsible for some losses, though not especially serious on pear. The larvae, feeding in the calyxes and fruit, do serious injury in scabbing the fruit.

On Prune. The rapidity and thoroughness with which the destruction of the prune crop takes place when once severely attacked by thrips, places this fruit in the first rank as a host. The thrips ordinarily emerge from the soil a few days before the prune blossom clusters are sufficiently open to permit them to enter. They may be seen on the twigs in enormous numbers awaiting opportunity to gain entrance to the blossom. Once inside they burrow to the heart of the blossom and attack the tenderest parts. Completely hidden within the tightly-closed blossom, they are protected from spray. The blossom cluster is very tender and the destruction is quickly wrought; the blighted buds, brown and dead, may be dislodged with the slightest touch.

Fig. 22. Condition of buds (cherry, prune, pear, respectively) at time of pear-thrips attack.

The adult thrips migrate from seriously blighted trees to adjacent less-injured orchards. Here egg deposition takes place and often trees that escape serious injury by the feeding of the adult thrips will suffer a heavy fruit drop from the effect of egg deposition in the fruit stems. The larvae likewise cause a great deal of damage. In years when the numbers and destructiveness of the adults are reduced, or in orchards adjacent to those blighted by the adults, the characteristic larval injury develops. The larvae feed in the calyxes and on the developing fruit, causing a characteristic leathery condition, known as prune scab. They

also attack young leaves, feeding along the midrib. The leaves become slightly cupped and riddled with holes along the ribs and veins. Frequently the devitalization of the tree, due to the oviposition by the adults and the feeding of the larvae, serves to reduce the crop to a negligible factor, though the trees escape the serious feeding injury by the adults.

Other Fruits. Apples, while heavily attacked, seem able better to withstand the thrips and do not suffer to the same extent as pears. Cherries may be seriously injured, though probably the most common type of destruction here is due to the very heavy egg deposition in the fruit stems by the adults, the long stems of the cherry appearing particularly attractive for this purpose. Peaches occasionally suffer severely in California and one may expect some losses on this crop in years of unusual thrips abundance.

HOST PLANTS

While particularly a pest of deciduous fruit trees, the pear-thrips has a fairly wide range of host plants and the number of known hosts is steadily increasing. This fact is of particular importance in connection with the consideration of its control, extermination, or the checking of its dissemination.

The host plants include: apricots, apples, almonds, cherries, figs, grapes, plums, pears, prunes, walnuts, maple *(Acer macrophyllum)*, madrona *(Arbutus menziesii)*, wild California lilac *(Ceanothus thyrsiflorus)*, poison oak *(Rus diversiloba)*, dog wood *(Cornus sp.)*, acacia, willow *(Salix sp.)*, laurel *(Umbellularia californica)*, mustard, live oak *(Quercus wislizeni)*, miners lettuce *(Montia perfoliata)*, June berry *(Amalancher florida)*, flowering currant *(Ribes sanguineum)*, choke cherry *(Prunus demissa)*, Nuttall's cherry *(Nuttallia cerasiformis)*, Douglas fir *(Pseudotsuga mucronata)*, Oregon grape *(Berberis nervosa)*, daisy, dandelion, and various ornamental shrubs, weeds, and grasses.

DESCRIPTION

The adult pear-thrips or "prune cootie" is very minute, about one-twentieth inch long, slender, dark brown in color, and with two pairs of slender, fringed wings lying down the back. The insect is fairly sluggish, moving with a gliding motion. The mouth parts are arranged

Fig. 23. The pear-thrips (Taeniothrips inconsequens) adult in act of ovipositing in fruit stem (enlarged 126 times). (After Cameron and Treherne, Can. Dept. of Agric., Bul. 15.)

as a projecting cone adapted for sucking, but armed with a rasping surface which permits the insect to lacerate the tissues. In feeding, the thrips first rasps or scrapes the surface of the plant tissue until bleeding takes place, then sucks up the plant juices.

The egg is microscopic in size, whitish, and shaped like a kidney bean. The eggs are placed within the plant tissue by the ovipositor of the female.

The larva is white in color, about one-twenty-fifth inch in length, slender like the adult thrips. During the period of activity of the larvae in the fields they may be found in the calyxes of the fruit and congregated in numbers on the under surface of the leaves along the depressions adjacent to the midrib.

LIFE-HISTORY AND HABITS

The winter is passed in the soil at a depth of from 3 to 36 inches, depending on the nature and type of soil. By far the majority of the thrips are found at depths between 8 and 11 inches. Most of the thrips occur in the soil as adults after early January.

Fig. 24. Egg scars on young apple stems. Larvae of pear-thrips have emerged, rupturing the tissues and thus accentuating the scars. Enlarged. (After Cameron and Treherne.)

The emergence of the adult thrips from the soil in the spring takes place about the time the pear blossom cluster buds begin to open. This date will vary with the season, but is from about March 15 to April 5.

Climatic conditions at this time will determine to a very large degree the magnitude of the infestation. Generally speaking, with sunshine prevailing and an air temperature of about 51° to 52° F., the thrips swarm out of the soil and to the trees in countless numbers. Rains and cool temperatures tend to check the migration from the soil and while thrips continue to appear, the period of emergence is much prolonged and usually results in a material reduction in the numbers of thrips and in the severity of their attack.

The adult thrips fly to the trees and commence their destructive feeding on the developing blossom buds. After a few days, egg deposition begins. As indicated, the eggs are deposited within the plant tissue by the sharp ovipositor of the female. Leaves and leaf stems are utilized for oviposition, but a favorite position is the fruit stems.

Where the infestation is heavy and a wholesale blighting of the blossoms occurs, the thrips soon migrate to adjacent orchards. Here eggs are deposited in numbers. One female probably deposits from 70 to 150 eggs. The egg stage averages about nine days. The larvae on hatching continue the destructive feeding practices of the adult. The larvae require about three weeks to complete their growth. When mature, they drop to the soil and burrow down for a considerable depth. In the soil they squirm about until a little earthen cell is formed. They rest here till early fall, when they pass through their transformation stages and by January 1 occur in the soil mostly as adults.

DISTRIBUTION IN OREGON

Unfortunately, due to the limited funds available and the pressure of other duties, complete surveys were not possible in 1919. In 1920 adverse weather conditions interferred with the proper carrying out of a rather elaborate survey as planned. The limits of the infestation, however, have been fairly accurately determined.

Fig. 25. Cherry infested with larvae of pear-thrips. (After Cameron and Treherne.)

The centers of infestation appear to be a small area in northern Linn county, the Liberty district south of Salem, and a few orchards in eastern Polk county south and east of McCoy. The area of infestation extends about twelve miles north of Salem, about nine miles west, about eight miles east, and south to northern Linn county. Heavy larval injury was apparent this summer on trees in northern Linn county; in Marion county near Shaw in the Liberty district and south along the river to Rosedale and north of town about four miles. The outskirts of the infestation and the more heavily infested areas are indicated on the accompanying map (Fig. 26).

HISTORY AND POSSIBILITIES OF THE THRIPS

To attempt to foretell the future of the pear-thrips in Oregon is necessarily problematic. The history of the pest in New York, California, and British Columbia affords a fairly reliable criterion of its possibilities.

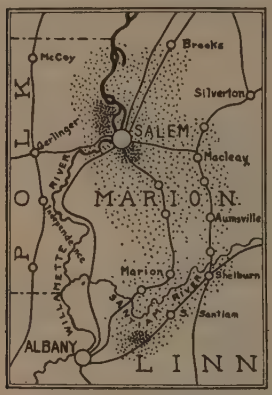


Fig. 26. Map showing area of infestation by pear-thrips in Oregon.

In all of these areas there has been a marked variation in the severity of attack in succeeding years. As a rule, there is a period of years, early in the infestation, when the destruction, some seasons, is very heavy, resulting in a total loss of the crop. There is a tendency for the wholesale destructiveness to lessen after a period of years of heavy losses. Likewise, in orchards where total destruction occurs one season, the infestation the succeeding year tends to be lighter; while in adjacent districts where the infestation was light, the injury may be severe the succeeding year. As a whole, in fruit districts where the pear-thrips is thoroughly established, the crop yields are materially reduced in quantity and quality unless an organized and intelligent spray program is adopted.

It must be conceded that up to date in Oregon there are many other contributing factors which have influenced the indifferent yields and generally devitalized conditions of the orchards. This fact does not materially change the general situation of the presence and destructive possibilities of the thrips in the infested areas.

In New York. First recognized as a destructive pest in 1911, though serious losses from an unknown source, now attributable to thrips, had occurred for about four years previous. The serious injury is confined to pears. While found in limited numbers elsewhere, the area of heavy infestation and destructiveness is confined to a limited area of the Hudson Valley. The spread of the insect has been slight and the injury in recent years possibly not so pronounced as formerly. The growers in the infested area generally spray for thrips control. The concensus of opinion is that this routine spray program year after year, while failing to prevent thrips injury entirely, nevertheless minimizes the losses and prevents the thrips assuming its earlier destructive proportions.

In California. The first injury recorded as due to pear-thrips was in 1902 in Santa Clara Valley near San Jose. By 1905 the thrips was well established and seriously destructive over a good share of the prune section of Santa Clara county and was present and destructive in limited areas of pears in Contra Costa county. Heavy crop losses were sustained in 1905, '07, '08, '09, and '10. Many growers suffered a total loss of

the crop for a period of three years during this time. Apparently the wholesale injury has tended to lessen in California since about 1912 to 1915. Pear growers in Contra Costa county carry out consistently an annual pear-thrips spray program. Thrips injury has become a negligible factor in Contra Costa county and maximum yields of high-grade pears are the rule.

Prune growers in Santa Clara county practice no regular spray program for thrips control. It seems the concensus of opinion that the thrips has "run its course," is no longer doing injury, and that a seasonal spray program is no longer necessary. There is justification for a difference of opinion here, but evidence obtained from the most reliable sources available would indicate that as a general rule there is a marked reduction annually in the quantity and quality of the prume crop in Santa Clara county due to the presence and activity of the thrips.

In British Columbia. The presence of the pear-thrips in destructive numbers was first discovered on Vancouver Island near Victoria in 1915. Authorities consider that it was probably present there for ten years previous. Crops of prune and pear in limited areas of this infested region have been practically a complete commercial loss for a period of seven years. The thrips has spread all over Vancouver Island and the adjacent islands of the Gulf of Georgia. In addition to fruit trees, maple trees are seriously blighted by the thrips.

Growers generally regard the pear-thrips as a serious menace and have adopted the annual practice of a full thrips spray program. Climatic conditions materially affect the abundance and destructiveness of the thrips from year to year, but spraying in any event is deemed a wise precaution.

CONTROL

Because of the lateness of the season and the progress of the infestation when discovered in 1919, no experiments in control were undertaken by the Experiment Station.

Plans were perfected for rather elaborate spray tests in the spring of 1920. Warm temperatures encouraged plant growth unusually early. These early favorable temperatures were succeeded by an extended period of cool, cloudy weather, with frequent rain. This condition prevailed throughout the bud development and blossoming stages, resulting in the blossoming period being prolonged and unusually late.

The adverse climatic conditions, with excessive cool and rainy weather, prevented the thrips emerging in numbers or becoming excessively abundant at any period. No cases of wholesale destruction by the adult thrips such as occurred in 1919 were observed. Injury by egg deposition and larval feeding were therefore the most generally serious type of thrips injury in 1920. The climatic conditions made spray applications impossible, or, where applied, of little or no experimental value and, the absence of thrips in numbers likewise hindered effective tests being made. Therefore, while a number of spray applications, comparable in time of application to the first standard thrips spray, were applied, no tangible data of experimental value were obtained.

The standard thrips spray program contemplates three applications of spray: two for the adult thrips and the third spray for the larvae. The time of application of these sprays will vary with the season, but must be timed to correlate with the proper development of the tree and the activities of the thrips.

Until trials are completed under Oregon conditions, therefore, it is suggested that we adopt with but slight modifications the program as recommended by British Columbia authorities following their careful experiments in control and at present practiced by their growers.

The experience of growers and the reports of experts is that in combating the pear-thrips absolute thoroughness and timely application are essential to successful control.

Power sprayers in good working condition maintaining a pressure of 175 to 200 pounds are desirable. The spray gun does not lend itself to successful thrips spraying. Use a rod fitted with an angle nozzle of the disc type. For the first application a disc with a fairly large aperture should be employed to afford a driving spray. Hold the nozzle close to the tree and drive the spray into the buds. For large trees the spray rig should be fitted with a tower to permit the spray to be applied from the proper angle.

The climatic factor must play an important part in the execution of our spray schedule. In a season such as 1920, there is little practical value to be obtained from the early spray and its effective application is impossible. The wise course would appear to be: have sufficient materials on hand for the first spray application and have the equipment ready. Then if the spray is required, valuable time—time absolutely essential to effective control—will not be lost in preliminary activities.

SPRAY CALENDAR FOR THE PEAR-THRIPS

Number and times to spray	Mixture for severe infestation	Mixture for light infestation
1st Spray: Pear blossom buds bursting. Thrips on twigs or entering buds March 15 to 25.	Miscible oil No. 2.. 5 gals. Black Leaf 40..... 1 pt. Water .....200 gals.	Ditto mixture for severe infestation or may substitute whale oil soap 10 lbs. for oil emulsion.
2d Spray: About a week before the blossoms open. April 10-20.	Miscible oil No. 2. 2 gals. Black Leaf 40..... 1 pt. Water .....200 gals.	On pears add nicotine sulfate to regular pink or preblossom spray. On prunes, fish oil soap 10 lbs. water 200 gallons.
3d Spray: Petals falling. Larvae in calyx cups and on under surface of leaves.	Miscible oil No. 2. 2 gals. Black Leaf 40..... 1 pt. Arsenate of lead.. 4 lbs. Glue ..... 2 lbs. Water .....200 gals.	On pears ditto above, adding nicotine to regular sprays where possible.

FLAT-HEADED BORERS WHICH ATTACK ORCHARD TREES AND CANE FRUITS IN OREGON

By W. J. Chamberlin

There are over 350 known species of flat-headed borers in the United States and some fifty species occur in Oregon. The members of this group are all borers in the tissue of woody plants and are of major importance as forest and shade tree pests. Several species, however, do attack fruit trees and at least one species attacks cane fruits in this State.

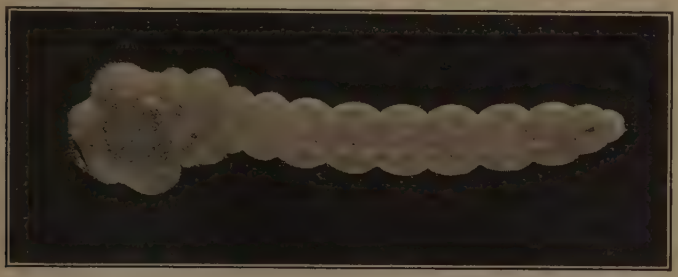


Fig. 27. Typical flat-head borer larva showing general appearance.

The flat-headed borers are the larvae or grubs of bettles, known as metallic wood borers, and belong to the family *Buprestidae.*

CHARACTER OF THE INJURY

The larval mines or worm holes usually occur beneath the bark in the main trunk or roots of the tree. They consist of long, winding tunnels, small at the start, but gradually widening out as the larva grows and progresses. The mines, in most cases, are packed with borings and excrement arranged in arc-like layers. The tunnels are in the cambium, engraving both the bark and the wood. The end of the larval mine is widened out into an oval cell.

The effect of the mines of the larvae, where numerous, is to girdle the tree completely. This, of course, cuts off the food and water supply and results in the death of the tree.

Conditions Favorable for Attack. Although native to the American forests, these insects seem to have found no difficulty in adapting themselves to introduced trees. The larvae feed and thrive in many species of introduced and cultivated plants, even when trees are at hand that were apparently their original species of host trees. The beetles seem to prefer the south, southwest, or sunny side of the tree for depositing their eggs; hence the larvae are more often found there. Young, recently transplanted stock is especially liable to attack the first year. Devitalized, weakened, and injured trees are frequently attacked. The devitalized conditions may have been brought about by starvation, poor soil, poor drainage, winter injury, sun scald, injury from cultivator or other machinery causing mechanical abrasions, or by rodents. Trees devitalized by any of the above conditions, as well as badly leaning trees, are especially subject to attack, and on such trees the attack is likely to be successful.

Conditions Unfavorable for Attack. If trees are well cared for, kept growing thriftily in an upright position in fertile soil, and not damaged mechanically; and if dead, dying, or injured trees or logs (even cordwood) of any species of tree which is listed as a host, are not allowed

to remain in the immediate vicinity, the orchard and shade trees are not likely to be attacked. Generally speaking, if an attack is attempted on healthy trees the chances are very good that the buprestids will fail, since the sap flow in a good, healthy tree will usually drown the young larvae in their tunnels before they succeed in entering the tree for any distance.

Evidence of Attack. In some cases it is very difficult to detect the presence of the borers. The evidence of attack will appear at first as a moist area on the surface of the bark. Later this area dries and the bark appears dark in color and sunken; successive generations of the borers may enlarge this sunken area, and the larvae will often be found just where the living and dead tissues meet. The bark on these depressed areas may crack and expose the borings of the larva which is working within.

DESCRIPTION AND HABITS

The *larvae* are hardly to be mistaken for any other borer, since all the species with which the orchardist will come in contact, in this State, are of the typical buprestid type. The distinguishing characteristic is the so-called flat head, which in reality is not the head at all, but the first segment behind the head. This segment, which is broad and much flattened, will usually serve to identify the pest. In addition, the larvae are composed of thirteen body segments, the first three (sometimes four) being broader than those which follow, and the last segment much smaller (Fig. 27). The first segment has a characteristic plate or area on both surfaces; this area may be bisected by a single line or it may be marked with an inverted V or Y.

The *adult* beetles will seldom be seen by the orchardist. Most of these beetles are flattened, more or less elongate oval, with short, inconspicuous antennae, and of bright, metallic colors.

General Habits. The beetles are very active, swift in flight, and run rapidly over the surface of tree trunks or logs. The female deposits her eggs singly (several eggs may be deposited close together, but never in clusters) directly on the smooth, exposed surface of the bark or under loose bark scales, but more often in crevices of the bark.

The hatching larva leaves the egg by boring through the lower surface directly into the bark of the host. This entrance hole will be quite small, but as the larva grows the mine enlarges and winds through the cambium. When the larva completes its growth it excavates an oval cell about one-half inch long and one-quarter inch broad, in which the change from the larva to the pupa and from the pupa to the adult takes place. The beetle eats its way to the surface through the bark, leaving an oval emergence hole. Mating takes place soon after emergence and the male dies, as does the female, after depositing her eggs.

General Seasonal History. The eggs are deposited principally during June and July; the larvae mine the bark and wood of the tree for the remainder of the summer and are more or less active throughout the winter when the weather is not too severe. Most of the larvae spend two years in the host, pupating early in the spring of the second year; the pupal stage lasts from three to six weeks or longer and emergence is from May until August, with the majority of the beetles appearing in June and July.

PREVENTION AND CONTROL

Natural Enemies. Adult buprestids have few enemies, but the larvae are more or less subject to natural enemies. Various species of woodpeckers and sap suckers prey upon them, tearing out sections of the bark in order to get at the grubs.

Various predaceous and parasitic insects also prey upon the larvae and pupae. Ants and clerid beetles are the principal beneficial predaceous

insects, while several species of ichneumon and braconid parasites are responsible for the destruction of a large number of the immature stages.

Preventive Measures. Control is difficult, and prevention is much simpler. Perfectly normal, healthy, vigorous trees are seldom attacked, and if the beetles become very numerous and do attack such trees the larvae are usually drowned out by the excessive flow of sap. It is very essential, therefore, that all those practices which are marks of the progressive orchardist be carried out, such as thorough and careful cultivation, fertilization, pruning, and spraying. Trees injured in any way, whether broken from heavy loads of fruit, from storm or where the cultivator may have broken the bark; in fact, any mechanical injury should be carefully repaired and the exposed parts painted over with white lead or a good tree paint. It has been found that leaning trees are more subject to attack than are upright ones. Low-crowned trees shade their trunks better, hence are less liable to attack. Young stock is especially liable to injury and may be protected by placing an upright board adjacent to the southwest side of the tree so that the trunk will be shaded. The beetles much prefer depositing their eggs where the sun is shining bright and hot; consequently, any device which shades the trunk acts as a protection against egg deposition.

Where signs indicate the presence of borers, the tree should be carefully examined and the larvae removed with a sharp knife. Make the wound as small and neat as possible, since jagged wounds offer better opportunity for reinfestation. All wounds should be painted over after the borers are removed.

Traps have been recommended in the East, but have not, so far as known, been tried in this State. In many places where these beetles appear to be doing considerable damage, however, the trap method may well be tried. It consists in putting up posts cut from any of the host trees mentioned for the species, placing these posts through the orchard and coating them with tree tanglefoot or any lasting, sticky substance. The value of this method lies in the fact that during the period of egg deposition the females fly from tree to tree seeking a suitable place to oviposit and many of them will alight upon the trap poles and be destroyed. Trap poles, prunings, dead, dying, and badly injured trees of all species which may serve as hosts for the beetles should be removed from the vicinity of the orchard or burned. This should be done in the fall.

Mechanical protectors in the shape of burlap or heavy paper, if wrapped securely about the trunks of the trees, will serve to prevent the deposition of eggs. The wrappers should extend from the ground up to the lower limbs and should be securely tied at the top and mounded with earth at the bottom. Wrappers must be applied by the time the trees put out their blossoms and may be removed late in the summer.

Certain repellent washes serve to prevent some of the beetles from depositing their eggs on the tree trunks; in addition, some of these washes are a benefit to the tree by cleaning the trunks of scale and fungi.

Alkaline Wash for Flat-headed Borers. Soft soap (fish oil or whale oil soap may be substituted), to which is added enough caustic potash or washing soda solution to form a product which may be applied with a brush, may be used at the time the borers start emerging in the spring. Crude carbolic acid may be added at the rate of one pint for each ten gallons of the wash.

THE FLAT-HEADED APPLE-TREE BORER

(Chrysobothris femorata Fab.*)*

The adult beetle measures about one-half inch in length and a little less than one-quarter inch in width. The body is somewhat flattened, of a dark grayish-brown color above, the gray color being in bands and spots;

under parts are brassy. When the beetle is in flight, the back of the body and under part of the wings show a bright metallic green. The fore legs are armed with teeth. In flight the beetles produce a slight buzzing sound and usually alight on logs or tree trunks with a click.

The **eggs** are flattened, oval, milky white, ribbed, and are about 1/25 inch in diameter.

The **larvae** is of the true flat-head type as described above; when full grown it is about three-quarters inch long. The dorsal plate on the first segment is marked by a distinct inverted V.

The **pupa** resembles the adult in general shape, but lacks color; the wing pads and appendages are folded against the ventral surface of the body. The pupae may be found in oval cells in the bark.

Distribution. The flat-headed apple-tree borer has been reported from practically every state in the United States as well as the southern provinces of Canada.

Economic Importance. Although this species is very destructive in certain sections, especially to apple trees, its importance in the West has undoubtedly been overestimated, since over 80 percent of the damage which in the past has been attributed to this species, is in reality due to the work of two closely-allied species, *Chrysobothris mali* and *Dicerca pecterosa*, which are treated in the following pages. However, *C femorata* is capable of doing severe damage, especially to shade and ornamental trees, and should be watched for on grounds where any of the above-mentioned host trees are grown.

Hosts. The known food plants of this species include the following fruit trees: apple, quince, pear, cherry, prune, plum, and apricot. It is also known to attack currant bushes. Aside from the fruit trees mentioned, the larvae mine the trunks of twenty-eight species of forest and shade trees and shrubs. It may be expected to attack the following native and cultivated trees in Oregon: sycamore, black walnut, chestnut, oak, maple, willows, black cottonwood, aspen, Lombardy poplar, Fremont poplar, Oregon alder, white birch, and wild plum, as well as hackberry and redbud.

THE PACIFIC FLAT-HEADED APPLE-TREE BORER

(Chrysobothris mali.)

The adult of *C. mali* is smaller than *femorata*, of a dull coppery red color with more or less distinct bright coppery spots on each wing cover, under parts cupreous. Easily distinguished from *femorata* by its smaller size and coppery color. (Length from .3 to .5 inch.)

The **larva** is very similar to that of *femorata* except for its smaller size. When full grown the larva of *mali* measures from ½ to ⅝ inch in length.

The **pupa** resembles the adult in size; it is white or yellowish white in color. The various appendages of the adult are plainly discernible in the pupa.

Distribution. The Pacific flat-headed apple-tree borer is found in Washington, Oregon, California, Nevada, Utah, Arizona, Colorado, New Mexico, and Manitoba (Canada).

Hosts. The trees and plants attacked in this State are: apple, plum, peach, cherry, prune, and apricot among the fruit trees; currant and gooseberry of the cane fruits. Maple, elm, willow, oak, wild plum, sycamore, poplar, alder, chestnut, and beach, whether growing naturally or for ornamental or shade purposes, are also attacked. Rose bushes and other ornamental shrubs are attacked in California and may also be attacked in Oregon.

Character of the Injury. The larvae mine the cabium of the trunk and limbs of the various hosts. When found working in the roots of prune and peach the larvae have a tendency to enter the wood more,

while in the case of gooseberry roots, the mines go to the center, where the pith is eaten out.

Natural Enemies. Several species of wasp-like parasites (Hymenoptera) have been bred from wood containing this buprestid. Only one *(Dorcytes cingulatus* Prov.*)* has been identified; all are more or less alike, being small insects with black-and-red, slender bodies, four membranous wings, and a long, flexible, needle-like appendage fastened to the anal end of the body. This is the ovipositor, and by means of it the female forces her eggs into the body of the flat-head larva beneath the bark.

The most common parasite of *C. mali* in Oregon seems to be the mite *(Pediculoides ventricosus)*, which belongs to the small family *Tarsonemidae.* These are minute, soft-bodied creatures. They attack the larvae and pupae in their tunnels, swarming over their host in numbers and sucking out the body fluids of the borers.

Records of this Station show that either *Chrysobothris femorata* or *C. mali* have occurred at the following places in Oregon:

Elkton: Killed numerous apple trees.

Aims: All trees in one orchard killed first season after being set out.

Carlton: Many young maples killed by *C. mali.*

Oregon City: Numerous in both prune and apple.

Maryville: Causing some loss to apple trees.

Roseburg: Noted in apple, prune, and peach trees.

Medford: Found quite abundant and doing considerable damage to pears, apples, and cherries.

Salem: Roots of gooseberry infested with *C. mali* have been received from the section northeast of Salem.

Corvallis: Both currant and gooseberry roots have been found infested in the vicinity of Corvallis.

THE FLAT-HEADED PRUNE-TREE BORER

(Dicerca pecterosa.)

The adult of this flat-headed borer is more robust in form than the previously mentioned species. The sculpture is rough; color blackish-bronze; length from ½ to ⅝ inch.

The **larva** resembles the larva of the flat-headed apple-tree borer, but is slightly larger, averaging about one inch in length.

The **adult** beetles, though very rare, have been captured by placing screen cages about the base of trees that are infested with the peach and prune root borer. The adults prefer to deposit their eggs in the edge of wounds low down on the trunk. The borer works in the cambium around the wounds caused by the prune root borer. When several of the flat-heads attack a tree infested with the root borer they soon girdle and kill the tree.

Up to the present time this beetle has been observed damaging fruit trees in only two sections of the State. At The Dalles it occurred quite frequently in peach trees, and at Roseburg was found doing considerable damage to both peach and prune.

Hosts. The native host plant is not known with certainty but is probably wild plum; the larvae bore into peach and prune.

Distribution. California, Idaho, Nevada, Utah, and Oregon. A considerable portion of the flat-head damage to peach and prune in Oregon, which has been attributed in the past to *Chrysobothris femorata* was very probably due to this little-known species. Adult beetles have been taken at Sumpter, Klamath Falls, Rogue River, Ashland, Roseburg, Corvallis, Oregon City, and The Dalles.

A similar species to the last but larger is *Dicerca hornii* less roughly sculptured, and of a shiny bronze color. Occurs in Montana, Idaho, Washington, Oregon, and California.

The native host plants of this species are many and varied. In Oregon it bores principally in the trunks of brush-like plants such as sumach, buck brush, and deer brush, also in alder, oak, and madrone. In California it attacks the cultivated plum and cherry and should be watched for in this State especially in the Rogue River section, where it is rather common in its native hosts.

The larva is similar to that of *Dicerca pecterosa* but larger, being about 1½ inches in length when full grown, and will be found working in the middle and upper trunk and occasionally in the larger limbs.

GRASSHOPPER CONTROL IN OREGON

By B. B. Fulton

Plagues of locusts or grasshoppers have had a profound influence on the welfare of mankind since the very dawn of history. No quarter of the globe is free from their depredations, and each great faunal area has its own destructive species which are peculiar to the region they inhabit. In years gone by a grasshopper outbreak was regarded as a public calamity, which no human power could prevent. In recent years entomological science has developed methods of combating grasshoppers and has shown that by the united action of the people in a community the grasshoppers can be successfully controlled.

Grasshopper outbreaks of serious magnitude in Oregon are confined to the great plains areas of the eastern and southern parts of the State. The grasshoppers responsible for this type of injury are of the so-called migratory type. They tend to breed in rather restricted areas of uncultivated or waste land, choosing certain rather definite types of topographical and soil conditions for the breeding ground. Outbreaks of lesser severity and local in their range occasionally occur in Western Oregon. These are usually due to the so-called non-migratory type of grasshoppers, which breed in or adjacent to the cultivated fields and may under certain circumstances move into and destroy crops. Young orchards adjacent to barren hillsides probably suffer most from this type of hopper.

In order to give an idea of the extent and frequency of grasshopper outbreaks throughout the State, the following summary is given, including the cases which have been brought to our attention within recent years through personal surveys or by requests from correspondents for information or aid in combating the pests.

GRASSHOPPER OUTBREAKS BY COUNTIES

County	Years	Remarks
Clatsop	1918	Injury local but serious.
Crook	1920	Serious outbreak in eastern part.
Grant	1914-1920	Outbreaks in two parts of county. Total loss of crops over large areas in '17, '18, '19. Experiment station gave three weeks' assistance in 1920, resulting in destruction of grasshoppers.
Harney	1915-1919	Losses ran into large figure till 1918. College gave assistance in '18 and '19. Got practical extermination at small cost. Former annual losses estimated at $500,000.
Klamath	1914-1920	Serious outbreaks in '14, '15, '18, '19 and '20. Experiment station helped in '14 and '15 College assisted in '18 and Government expert assisted county agent in '20. County agent in charge in 1919. Outbreaks in several parts of county.
Lake	1917-1920	Thousands of acres of hay and grain destroyed in '18. Serious outbreaks have developed in other parts of county more recently.
Linn	1915-1917	Local.
Marion	1917	Local.
Morrow	1918-1919	Light.
Polk	1917	Local.
Umatilla	1915-1919	Steady increase in spread and severity.
Union	1920	Local, moderately serious. Experiment station gave aid.
Wasco	1914-1915	Heavy injury to spring grain; total loss of oats; corn and potatoes hit hard. Station helped in 1915.
Wallowa	1916	Not widespread.

The most destructive species of grasshopper in Oregon and our only true migratory form is known as the clear-winged locust *(Camnula pellucida)*. It occurs in practically all parts of the State where open fields are found. The arid conditions prevailing east of the Cascades are most favorable for its increase, and each year several localities report serious outbreaks of this grasshopper.

There are several non-migratory species of grasshoppers in the State, which often become numerous enough to do considerable damage. The red-legged grasshopper *(Melanoplus femur-rubrum)* is the most common form in Western Oregon. A closely related species *(Melanoplus atlantis)* is abundant over most parts of the State, and occasionally develops migratory habits.

Fig. 28. Female of clear-winged locust depositing eggs.

LIFE-HISTORY OF THE CLEAR-WINGED LOCUST

During midsummer the clear-winged locusts mature, and millions of individuals, scattered over many miles of territory will congregate on certain restricted areas to deposit eggs. Within an infested district there may be many of these egg beds, varying in size from a few square rods to several acres. In any case the total ground covered by egg beds is but a small fraction of the devastated area.

The location of the egg beds depends on the character of the soil and topography of the infested region. It is difficult to tell just where to expect to find the beds and one of the best guides to follow is the movements of the grasshoppers in late summer. In general the eggs are deposited higher than the feeding grounds and usually in a hard soil, often stony, or one that is matted together with roots.

In depositing eggs the female first digs a nearly vertical hole in the ground with the tip of the adbomen. The eggs are then deposited in three rows of about eight or ten each. During oviposition the female secretes a mucilaginous substance, which, after hardening, holds the eggs together and retains a layer of the surrounding soil. When these egg masses are dug up in the fall they appear as earth-covered capsules about one-half inch long. In the spring the capsules break apart and reveal the eggs, which at first glance resemble wheat grains.

The hatching of the eggs begins in May and extends into June. The exact time varies greatly with the season and the altitude. Eggs near the surface hatch first. In rocky places or on clay ground that cracks badly, many of the eggs may be three or four inches below the surface, and under such conditions the period of hatching is greatly prolonged.

The newly hatched hoppers do not move away from the egg beds for several days, and if the weather is cool or rainy they may remain hidden in cracks. After they have molted and become a little larger they migrate rather rapidly.

The grasshoppers continue to move away from the egg beds and extend their territory until they become winged. After that they gather in great numbers in certain restricted localities, to mate and deposit eggs. From these points as centers hoppers are constantly going forth on foraging expeditions to the surrounding hay and grain fields.

NATURAL CONTROL

After a grasshopper outbreak has run a period of years in a locality the hoppers may move to another place where food is more plentiful, if the original spot is not too much isolated. Under other circumstances disease or natural enemies of the grasshoppers may so decimate their ranks that they remain no longer a serious pest. An outbreak of disease affects the adult grasshoppers only under certain weather conditions. The insect enemies of the grasshoppers work largely on the eggs. A species of bee-fly *(Bombyliidae)* is the most common insect of this class found about the Camnula egg beds in Oregon. The maggots may be found within the egg pods.

Gulls and other birds devour a great many grasshoppers during an outbreak. Turkeys and chickens are of value in destroying a good many hoppers each year, but during a severe outbreak they can do no more than gorge themselves, and soon need a change of diet.

METHODS OF DESTROYING GRASSHOPPERS

Various methods have been devised for controlling grasshoppers, including the use of hopper-dozers or catchers, spraying, brush dragging, trenching, cultivating egg beds, and killing by means of poison bait. Of all these the last mentioned has proved most efficient. To some extent the practice of plowing the egg beds or thoroughly cultivating them with a disk or spring-tooth harrow, can be used to advantage, but this is generally profitable only where the ground can be seeded to a crop.

The poison bait method of control is commonly used when the grasshoppers are actually feeding on the crop and by prompt application of the bait at this time the loss can be kept at a minimum. A much better system, wherever it can be employed, is to poison the hoppers while they are small and thus eliminate their destructive activity for that season, and prevent them from depositing eggs. As already pointed out, our most destructive locust deposits its eggs within relatively small and definitely limited areas of egg beds. The young hoppers hatching there can be poisoned in the spring before they have had time to spread. Much less material is required to poison in these confined areas. Where effectively done crop losses may be entirely prevented, and where vigorously followed up in an organized way practically wholesale destruction of the hoppers is possible.

THE POISONING CAMPAIGN IN HARNEY COUNTY

The following account of the grasshopper control campaign conducted in Harney county in 1918 and 1919 is given as an example of what can be accomplished by the use of proper methods.

In the fall of 1917 a large delegation of citizens called on the Harney county court and requested that something be done to check the ravages of grasshoppers. The court ordered a survey of the egg beds to be made and following that appropriated $3,000 for the purchase of materials. The survey was made by Mr. Roy McGee, a local rancher who had lost his entire crop by grasshoppers for the three previous seasons. In the spring of 1918, Mr. B. G. Thompson[13] was detailed by the Bureau of Entomology, United States Department of Agriculture, to direct the work in cooperation with the Oregon Agricultural College.

The campaign in 1918 succeeded in saving most of the crops, but did not destroy all the grasshoppers, largely because some of the egg beds had escaped notice and because weather conditions were adverse during the poisoning period. As a result, a large number of eggs were deposited by the hoppers that escaped.

[13]Much credit is due Mr. Thompson for the success of this campaign. His untiring energy, coupled with the united support of the ranchers and townspeople, made possible the results secured.

PLATE IX

(1) Spreading poison bait for grasshopper control. (2) Grasshopper egg masses. The two at left with earth covering removed. (3) Grasshopper eggs dug out of egg bed in spring.

It was decided to carry on the work another year. A very thorough survey of egg beds was made by Mr. Thompson and his helpers in the fall of 1918. The local organization was continued and in the spring of 1919 the court appropriated $6,000 for materials and employed three men to mix the poison bait. This was done by means of a box which turned on a shaft like a churn and was run by a small gas engine.

Mixed bait was taken to the fields in auto trucks and sown broadcast. Several types of endgate seeders were used but without success. Sowing by hand was found to be the most practical method. Ranchers handled the grasshoppers on their own ranches, but most of the egg beds were on unoccupied land. These areas were handled on a community basis.

As a result of the 1919 campaign no droves of hoppers reached the cultivated fields. The region was free from the grasshopper plague and no further measures have been necessary. The estimated value of this work as given by the Burns Commercial Club is summed up in the statement, "At a cost of $6,000 the county was saved a loss of $500,000."

CAMPAIGN IN GRANT COUNTY

During the spring of 1920 a similar campaign was carried on in Fox Valley, Grant county. The ranchers had organized during the winter and procured the necessary materials. Many of the egg beds were located beforehand, and a thorough search was made for others as soon as hatching started. Egg beds were scattered over most of the Valley, which is about ten miles across in both directions. To obtain cooperation in spreading the bait the egg beds were arbitrarily grouped into ten districts.

Under the direction of the writer, work began June 1. A mixing box similar to that used in Harney county was constructed. Under the local conditions it was found most practical to mix bait on alternate days. This was done on a community basis and the entire output of the day was sacked and carried away to the various ranches.

On account of weather conditions and the nature of the soil, the hatching period was greatly prolonged and it was necessary to go over the same beds several times.

At first the formula recommended by the United States Bureau of Entomology was used, which contains bran, arsenic, molasses, and ground oranges or lemons. Later, old pine sawdust was substituted for half the bran, and finally the sawdust alone was used and salt added in place of ground fruit.

The last mixture gave excellent results and saved several hundred dollars in cost of materials.

Following the poisoning campaign the grasshoppers were reduced to a negligible quantity and bumper crops were harvested for the first time in several years.

A campaign of the general plan outlined in the two cases cited above will suffice to handle most grasshopper outbreaks. Additional investigations should be made concerning other species of hoppers which are present and may become serious; the natural enemies, their value and possibilities; and a study of poison baits should be made, seeking possible improvements in their efficiency and cheapness.

ESSENTIALS OF GRASSHOPPER POISONING

Organization. In order successfully to carry on a grasshopper-poisoning campaign against migratory hoppers there must be an active organization of the people in the district concerned so as to insure cooperation under efficient leadership. Little can be gained by individual effort.

The organization should be perfected sufficiently early so that funds can be raised, materials procured, implements prepared, and egg-bed surveys made previous to the time for actual poisoning.

Materials. After a preliminary survey of egg beds, the amount of materials needed can be estimated. This should be figured on the basis of at least two pounds of arsenic per acre of egg bed, with other materials in proportion.

The standard mixture, recommended by the United States Bureau of Entomology, which has given uniformly good results, is as follows:

Wheat bran	100 lbs.
White arsenic	4 lbs.
Stock molasses	2 gals.
Oranges or lemons (ground)	2 doz.
Water, as much as possible without making the mixture difficult to scatter.	

A much cheaper mixture than the above was employed successfully in Grant county and will probably give as good results elsewhere. We recommend it with reservations.

Pine sawdust (dry)	75 lbs.
White arsenic	4 lbs.
Stock molasses	2 gals.
Salt	1 lb.
Water, as in above formula.	

Mixing Bait. For mixing small amounts of poison bait, with not more than a few hundred pounds of arsenic in all, a large, shallow, open box such as a mortar box can be used, and the materials mixed with shovels. This has the disadvantage of allowing the arsenic to blow about as a fine dust.

Where five hundred pounds or more of arsenic is to be used, a special mixing box is desirable. This can be made to turn on a shaft on the principle of a churn. Dimensions should be about four feet square by two and one-half or three feet, with a shaft running through the square sides. The inside should be smooth, without dashers, and one side removable for emptying. There must be no large cracks. The mixer can be turned by a small engine or horse-power machine, or by hand if a smaller box is used. The speed should be about thirty-five revolutions a minute; if faster, the bait does not mix well.

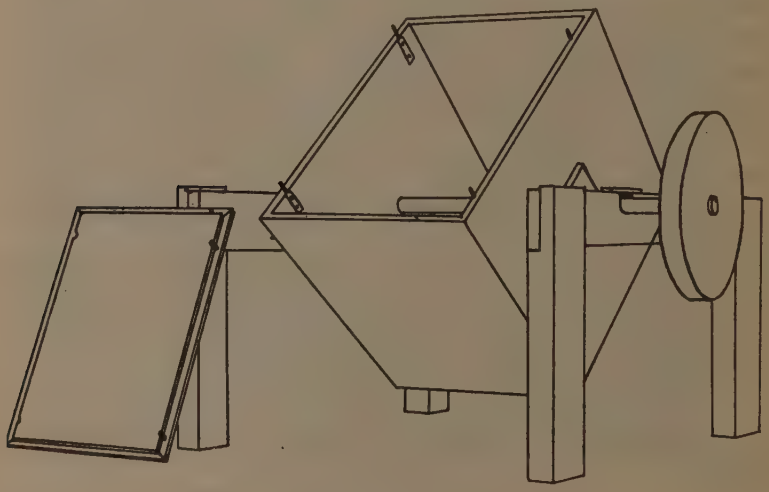


Fig. 29. Rotary type of mixing box for making poison bait.

Bran or sawdust should be mixed with the arsenic dry. Molasses should be dissolved in water in large cans and the ground fruit or salt in solution (according to formula used) should be added. This mixture is then added to the dry material.

Some practice is necessary in getting the right amount of water. The bait should be as wet as possible and still not drip excessively in the sack or be too soggy to break up well when it is spread.

The mixed poison bait can be kept in sacks for several days if necessary.

Spreading Bait. The spreading of poison bait on egg beds must be done systematically by several men working together. They should keep abreast, about ten to fifteen feet apart, and move slowly across the bed in a straight line. The man on one side should be close to one edge of the bed and when he comes to ground not infested with hoppers he should stop spreading, but move along with the others until he again comes to grasshoppers. The bed may be too wide to cover in one strip and in this case the inside man should mark his path as he goes across so that he can follow it back without missing any ground or covering it twice.

Do not waste the bait. It should be scattered thinly over the ground. The amounts given in the formulae should cover ten acres at one sowing.

Do not spread bait on cold or rainy days or during the middle of the day. A bright warm day is best, but spread only early in the morning before the sun gets hot or a little while before sundown. Generally speaking the hoppers devour the bait greedily only while it is moist.

It is very seldom that the ground will be covered with dead hoppers the next day after poisoning. For several reasons this may not happen. The poison acts very slowly; the hoppers crawl into cracks to die and before they are dead many more may have hatched.

On account of the migrating habits of the young grasshoppers it is not advisable to wait until all eggs have hatched before spreading the poison. Poisoning should begin as soon as the hoppers become very numerous and show a tendency to move away. The treatment will need to be repeated two or more times at intervals of several days or a week, depending on the weather, until all eggs have hatched and all grasshoppers are poisoned.

There is no danger of poisoning stock if the bait is properly scattered without lumps and no piles or open sacks are left in the field. Poultry should be kept away from poisoned areas.

THE ALFALFA WEEVIL

By B. B. Fulton

The alfalfa weevil made its appearance in the State of Oregon in 1919 or earlier and is now firmly established in a small area on the eastern border of Malheur county. The weevil is a native of Europe, where it is found in most alfalfa-growing districts, but apparently in no section there has it become a serious pest over a continued period of years. Under new environmental conditions found in the United States it has multiplied to such an extent that in some places the growing of alfalfa has become a difficult undertaking.

The spread of this insect has not been as rapid as was first predicted. It was first found in 1904 near Salt Lake City, Utah, and has since spread over most of the alfalfa sections of Utah and Idaho, and now occurs in parts of Wyoming, Colorado, Nevada, and Oregon. Its range has been extended most rapidly along main roads, although there has been a general spread due to the migrations of the adult weevils.

In Oregon the weevil has been found as yet only in Malheur county. The main part of the infestation lies between the towns of Ontario, Vale, and Nyssa. Bordering on this main infestation is an area several miles wide in which the weevils occur in constantly decreasing numbers as one approaches the outer limits.

The presence of the weevil in a district and its annual spread into new fields becomes a matter of particular interest to alfalfa growers in neighboring districts. This is due not only to the potentiality of the weevil as a pest, but also to the stringent quarantine regulations imposed by most states on the shipment of hay and other products from weevil-infested territory. For a few years after it has entered new fields the weevil does not become abundant enough to cause serious losses. At the extreme edge of its range the infestation is usually so slight that it is somewhat difficult to determine the exact boundaries of the weevil-infested territory. The first effect of the weevil to be felt by alfalfa growers then, is the influence of quarantine regulations on the market for hay. In sections where the hay is all consumed locally this effect will not be so apparent, but where large quantities are normally shipped

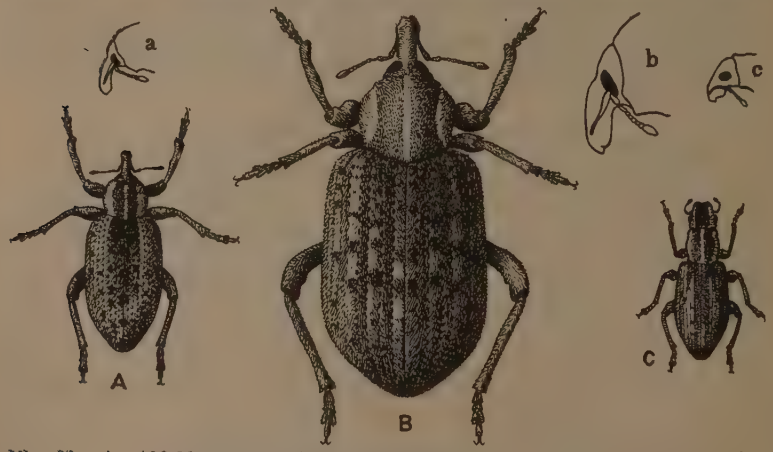


Fig. 30. A. Alfalfa weevil. B. Clover-leaf weevil. C. Clover-root curculio. Above, profiles of heads (respectively), enlarged 6 diameters.

out, the local alfalfa growing industry and associated business may suffer serious depression.

Several insects can be found in alfalfa fields in Oregon which might easily be mistaken for the alfalfa weevil. Two species of weevils that resemble the adult to a certain extent are fairly common. These are the clover-leaf weevil and the clover-root curculio. The differences between the three species are brought out in Fig. 30. The clover-leaf weevil is a closely related insect. It can be distinguished by its much larger size, and rather robust build. The clover-root curculio is slightly smaller than the alfalfa weevil and resembles it superficially, but can be recognized by its shorter snout when seen in profile.

The larva of the alfalfa weevil is a green, wrinkled, worm-like creature, about one-fourth of an inch long when full grown (Fig. 31-A). It is characterized by its small black head and the whitish stripe down the middle of the back. None of the common green caterpillars found on alfalfa have a white stripe along the median dorsal line although some have stripes along either side. The larva of the clover-leaf weevil closely resembles the alfalfa-weevil larva, but since the former feeds mostly at night and lies hidden on the ground during the day the two are not likely to become confused.

LIFE-HISTORY

The adult weevils hibernate over winter, appearing in the fields early in spring, when they begin feeding on the young growth of alfalfa. Some few eggs are deposited in dry stems when the beetles first become active, but the majority are deposited several weeks later in the living stems of the alfalfa. The eggs are very small, oval, and bright yellow in color.

Some few larvae from the first eggs deposited may hatch out in March or April but the great majority appear in May and June. They crawl to young shoots and begin feeding. The leaves become riddled with holes and in a severely infested field a total loss of the crop may result, if no remedial measures are practiced.

When the larvae are full grown they pass to the ground and form cocoons among the fallen leaves and rubbish about the bases of the plants. The cocoon is a curious hollow network of whitish threads, oval in shape, and considerably larger than the insect within. (Fig. 31-B.) This cage-like structure acts as a protection for the insect while it passes through the pupal stage and finally becomes an adult weevil.

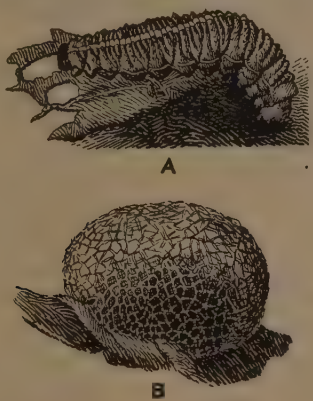


Fig. 31. Alfalfa weevil. A. Larva. B. Cocoon.

There is but one generation a year. The beetles that come out during the summer continue to feed to some extent on the second and third crops of alfalfa, but toward the end of the summer they go to the ground and remain in cracks or among the dead vegetation on or about the hay fields until spring.

MEANS OF CONTROL

After eleven years of experimental work on the alfalfa weevil the United States Bureau of Entomology has recommended control measures which they claim to be efficient and practical. These are summarized briefly as follows: An arsenical spray should be applied about one or two weeks before the first crop is ready to be cut. The best time is at what is known as the turning point, or when the young larvae have become numerous enough to destroy the growing tips. If sprayed at this time, the crop recovers quickly, the second crop sprouts and grows without delay. No treatment of the stubble is necessary. Spraying should be done if possible during a warm spell when the weevils are feeding actively. Lead arsenate is recommended, at the rate of two pounds (powdered) to 100 gallons of water, with a small amount of soap as a spreader. When the spray is applied at a rate of 100 gallons or less per acre there is said to be no danger of poisoning stock.

Nearly any kind of horse-drawn spraying outfit can be adapted to the purpose, by fitting it with a horizontal pipe bearing several nozzles, which should be about two feet above the plants and pointing downward. The nozzles should be about two feet apart, the number depending upon the capacity of the pump.

Investigations are being conducted by the Idaho Experiment Station to determine the value of dusting as a means of combating the alfalfa weevil. This method of applying the poison, if it gives the same degree of control, would seem to be much more practical than spraying.

Plans are under way to arrange cooperative tests between the Oregon Experiment Station and other institutions on the comparative value of dusting and spraying in the control of alfalfa weevil. It would seem that arsenical poisons afford the logical means of combating the weevil. The mechanical problem of efficient and practical applications is yet worthy of study.

Some cultural practices have been devised which help to keep down the infestation when spraying is not resorted to. A system of pasturing the first crop has been used to destroy the eggs and young larvae. The field is divided into two or three lots and each is grazed close before turning the stock into the next lot.

As an alternative, the crop may be cut green several times and used for feed. Another practice is to harrow and brush-drag the field after the removal of the first crop so as to create a dust mulch, which, together with the heat of the sun, kills most of the insects.

THE LOGANBERRY CROWN-BORER

(Bembecia marginata Harris.)

By A. L. Lovett

The crown-borer is one of the most commonly injurious insect pests of the cane fruits in Oregon. It attacks all types, including loganberry, blackberry, and raspberry. Because of the commercial interest in the loganberry in Oregon, we have termed it, for our purpose, the loganberry crown-borer, though it is more generally known as the blackberry crown-borer or the raspberry root-borer.

The larva, or borer, when mature, is slightly more than one inch long, white or waxy yellow in color with a reddish-brown head. The body is constricted along the ventral surface; there are three pairs of short legs near the head and the tip of the body is fitted with a fleshy proleg which assists the borer in propelling itself along. The name is significant of the situation where found and the type of injury done. In general the larva and adult resemble the prune root-borer and the injury likewise is of a similar nature (see Plate III). Plants appear sickly or dying. An examination of the crown and roots reveals large tunnels running through them and the borer resting in the tunnel. In older plantings where no control measures are practiced, as high as 30 percent of the plants may succumb in a season.

The adult of the borer is a showy, clear-winged, day-flying moth, wasp-like in appearance. The body is covered with scales, arranged around the abdomen as alternate rings of black and yellow.

HISTORY IN OREGON

The loganberry crown-borer was first discovered in Oregon in the Mt. Tabor district near Portland, about 1899. It occurred principally as a pest of blackberries. No notes are available on the prevalence and spread until 1911, though it was present and recognized as a serious pest in the older berry districts as they developed. By 1911 the pest was generally distributed over the State and a source of considerable concern in most commercial loganberry plantings.

Studies of the life-history and habits were made during 1913 and 1914 and found to correspond in general with the findings of W. H. Lawrence.[14]

Control studies were undertaken and have been continued mostly as cooperative field operations. The pest may be successfully controlled in commercial plantings at comparatively little expense.

LIFE-HISTORY AND HABITS

The insect passes two seasons as a borer in the crown of the plant. The adult moths appear in the field during August and are active until early fall. The earliest adult to emerge in our breeding tests appeared August 6. The moths deposit their eggs singly on the under surface of the margins of the leaf. The eggs are oval, rounded, the top flattened, the shell brittle and hard and of a deep reddish-brown color. Eggs in our tests required from forty to sixty days to hatch. The majority of the eggs, therefore, hatch in late September and October. The young larvae in hatching gnaw their way out through the end of the egg nearest the margin of the leaf.

The young larvae crawl down the canes to the base or crown of the plant. They make very good time, averaging six inches in five minutes, keeping on the side of the cane away from the light. In a few cases under observation, the young larva paused in its travel and after a brief rest, suspended itself by a silken thread and so lowered itself to the ground.

[14]Lawrence, W. H., The Raspberry Root Borer or Blackberry Crown Borer, Wash. Exp. Sta. Bul. 63, 1904.

Those larvae which successfully reach the crown of the plant, work their way below the surface of the soil and tunnel in just under the bark. Here they form a cyst or cell, appearing as a slightly raised blister on the surface of the crown. They become active as growth starts in the spring, tunnelling their way upward through the crown. By early summer they reach the base of one of the new season's canes and proceed to tunnel up the pith of this new cane a distance of two to twelve inches. In midsummer as half-grown borers they work their way outward and girdle the infested cane just beneath the bark. The infested canes, varying in length from eighteen inches to eight feet, following this girdling process, wilt and die.

The actions of the grub following the completion of the girdle may vary. In the majority of cases, however, previous to returning to the crown of the plant two acts are performed. The borer tunnels up the cane above the girdle a few inches, where it remains for some considerable time. Later, as it is returning to the crown of the plant, at a point somewhere below the girdle, the borer tunnels out an opening to the exterior of the cane, filling this burrow with frass.

In late autumn the borers return to the crown and root system of the plant, where they remain more or less active during the second winter. The succeeding spring they again work their way upward, now as mature grubs. They seek a dead stub or cane, possibly endeavoring to locate the dead cane injured the previous season. They crawl up the cane from one to four inches, appropriate the emergence hole already prepared or eat a tunnel to the exterior of the cane, leaving only the bark intact. They then drop back down the tunnel a short distance and transform to pupae. The pupa is a deep, reddish brown in color, capsule-like in appearance, with encircling rows of spines about the body. In August or later, when the adult moth is ready to emerge, the pupa begins a rocking motion in the tunnel. The rows of spines are so arranged that this rocking motion moves the pupa up the tunnel until it projects half way out of the emergence hole previously prepared by the larva. From this projecting pupal case the adult moth emerges to repeat the cycle.

CONTROL

The fact that the borer is within the tissue of the plant during its active period renders the application of sprays for the larva of no avail. Preliminary attempts to kill the eggs were unsuccessful. The materials used were: commercial lime-sulfur, 1-10; distillate oil emulsion, 1-10; "Yel-Ros," 1-40. The sprays were applied October 7, 1914. The results in all cases were negative.

Hand Methods in Control. Taking advantage of the habit of the borer in twice appearing above ground during its development, the following hand methods were attempted, found eminently satisfactory, and are recommended for use:

Go over the fields in early summer, early fall, and in the spring, suiting the work to the regular training up dates and the dates for cutting out old canes so far as possible. Look carefully for girdled or wilted canes. Where found, grasp firmly and give the cane a twist and a pull. The cane will sever at the girdle. Often the borer will be revealed in the severed cane. If one carries a short, heavy wire, this may be inserted into the tunnel of the severed stub to destroy those borers not occurring in the cane.

For severe cases, go over the field during late June and break off or cut out all dead canes and stubs close to the ground. The mature larvae that have come up for pupation will thus be destroyed.

If practice number one is followed consistently, practice number two may generally be dispensed with, though in unusually severe infestations a combination of the two should probably be followed for at least a season.

AMOUNTS OF SPRAY REQUIRED ON TREES OF DIFFERENT AGES IN THE DIFFERENT APPLICATIONS

By Leroy Childs

In connection with the investigational work on sprays and spray practices carried on at Hood River some interesting figures have been gathered relative to the amount of diluted spray required to obtain effective control of the various orchard pests present.

Of all the problems of spraying which come to the attention of the orchardist, the actual requirements of trees of different ages for different spray mixtures are least known and perhaps least seriously considered. To this lack of understanding can often be traced the failure to check the ravages of the many familiar insects and diseases. Thorough spraying is to be desired, but overspraying is a waste of expensive materials and time. Incomplete spraying, on the other hand, is a double disaster, a waste of materials and time, and a failure to control the pests. Every orchardist should more closely check up his average tree usage for every spray applied during the season. There is no more clear-cut method of telling just what has been done in the orchard, from the standpoint of spraying, than an analysis of this sort. With sprays of a similar nature in an orchard of more or less uniform trees, a very high degree of uniformity in the number of trees covered should be maintained with each tank of spray applied. If this is not maintained, there is something decidedly wrong in the technique of application. During years of a light crop growers who "spray for fruit" in their codling-moth control are frequently at a loss to account for the many wormy apples present at picking time. A study of the average quantity of spray used per tree in an orchard thus sprayed as compared to a well-sprayed orchard usually proves a revelation of startling inadequacy. Spraying for fruit in the case of both apple-scab and codling-moth—or for the control of other insects or diseases, for that matter—is not an advisable practice. In the early applications it is almost impossible to determine accurately whether a tree has fruit on it or not. If the missed or partly sprayed tree turns out to have a box or even a portion of a box of fruit on it, a large portion of the fruit will be found wormy. Not only is this fruit lost, but the very fact that a goodly number of worms have been propagated and have spread to surrounding well-sprayed trees results in a general increase in the percentage of wormy apples and a very decided increase in the percentage of "stings."

During the summer applications, that is, after the trees have developed a large proportion of their foliage, the spray requirements for each application are about the same. In orchards where careful records of spray usage have been obtained we have found that associated with irregular amounts of spray used is a very decided irregularity in insect and disease control. In numerous instances it has been observed that these irregularities—failure to use sufficient amounts of material (gallons per tree) in some of the sprays—has caused a loss through the increase in damaged fruit that would have more than paid the total spraying charges for the entire year.

The tree requirements for the different sprays used in combating our various troubles are quite varied. It has been found that in order to obtain a complete covering with the miscible oil spray—used largely for the control of the leaf-roller in the Hood River Valley—and applied as a delayed dormant spray, much more spray must be used than is needed for late spring and summer applications of arsenate of lead and lime-sulfur for the control of codling-moth and apple-scab. The reason for this greater requirement is due undoubtedly to the fact that the twigs

and branches must all be thoroughly covered if the desired results are to be obtained. In so doing the tree must be very carefully worked over and in view of the fact that, contrary to the usual belief, oil does not spread easily, a good deal of spray is lost in obtaining a complete covering. In the case of seventeen-year-old trees studied, about two gallons more per tree is used with the oil sprays than with the summer applications. The proportions were about the same in trees of other ages. Next in point of requirements comes the fall bordeaux mixture used for the control of anthracnose. Here again the essential factor involved is the thorough covering of all of the twigs, branches, and trunks, a procedure requiring more time and material than is found necessary for the coating of foliage and fruit in the summer sprays. It has been noted that about a gallon and a half more spray is required in the autumn on old, bearing trees to cover them completely than is required on the same trees during the summer. Table XII shows the average amount of spray per tree applied in well-sprayed orchards of different ages in the Hood River Valley, where very satisfactory results have been obtained.

TABLE XII. AVERAGE SPRAY REQUIREMENTS FOR BEST CONTROL ON TREES OF DIFFERENT AGES*

Age of trees	Miscible oil gallons per tree	Summer applications for scab and codling-moth	Fall bordeaux
11	4.1	4.1	...
12	4.5	4.5	5.0
13	5.6	4.5	5.1
14	7.0	5.2	...
15	7.2	5.6	6.1
17	8.0	6.0	7.4

*Based upon information obtained in a number of successfully sprayed orchards during the years 1917, 1918 and 1919.

THE RUSTY LEAF-MITE

By Frank H. Lathrop

From time to time, fruit growers have called our attention to peculiar foliage injuries on prune and pear. Upon examination of the injured foliage, we found the leaves to be heavily infested with a minute, eriophyid mite. Specimens sent to Mr. H. E. Hodgkiss, entomologist, Pennsylvania State College, were identified as the rusty leaf-mite, *Phyllocoptes schlectendali* Nalepa.

The Rusty Leaf-Mite is a minute creature, about .006 inch in length, so small as to be practically invisible to the naked eye. The mite is somewhat pear-shaped, being broadest at the head end, with a much elongated, tapering body. Four short legs placed near the head enable the creature to crawl about the leaf surface. The mite is provided with a short proboscis with which, in feeding, it pierces the leaf tissues and sucks out the juices.

Food Plants. We have found the mites on apple, pear, and prune. Examination of peach and cherry foliage failed to reveal the mites, although these trees were adjacent to infested apples and prunes.

Distribution. The mite seems truly cosmopolitan in its distribution. It is common in Europe and Asia. First reported in North America by Parrott[15] on apple foliage in New York, it is now evidently widely distributed on this continent.

In Oregon this mite has been found in every prune and apple district in which an examination has been made, including Imbler, La Grande, McMinnville, Salem, Corvallis, Eugene, Roseburg, and Medford.

INJURY

Injury resulting from attacks of this species was first called to our attention in 1917 at Salem, where prune foliage in the orchard of Mr. C. O. Constable was affected. Since that time, reports of injury have been fairly common from several fruit-growing districts.

Injury which we have observed on prune appears as a noticeable

[15]Parrott, P. J. Science, N. S. 23, page 7?, 1906.

Fig. 32. Rusty leaf-mite. Prune foliage showing typical injury.

curling of the leaves, a deepening of the red coloration of the tender terminal growth, and sometimes more or less russeting of mature foliage.

We have never observed noticeable injury to apple from this species, although we have found numerous instances of heavy infestation of apple foliage. Brittain[16] in describing injury to apple foliage from this source in the Okanogan district of British Columbia states: "In some cases the leaves present a red, rusty appearance, which gives the mite its popular name. More often, however, at least in the Vernon district, the leaves have a silvery appearance. On this account, the work of this pest is almost invariably confused with the disease called 'silver leaf'."

The most serious injury, resulting from the activities of these mites, occurs on pear. The most characteristic effect is a russeting of the infested foliage. We have observed this type of injury at Roseburg and, to a lesser extent, at Corvallis. O'Gara[17] observed a severe outbreak on pears at Medford in 1912, and was the first to describe the injury. According to him, the injury becomes apparent in late June or early July, and "the foliage has a peculiar rust or russet appearance on the under side and is somewhat curled, as though by drought." Russeting of the upper surface occurs, but is relatively uncommon. "Where the attack is serious, the whole tree has a brownish appearance. . . . During the latter part of July and through the month of August, badly injured trees shed the foliage from their terminals. . . ." The fruit is also russeted and cracks appear on the surface when injury is severe. Young trees suffer even more severely, and almost complete defoliation may result before the season's growth has been attained.

LIFE-HISTORY

The mites hibernate during winter, securely hidden beneath the bud scales of infested trees. Apple seems to be the favorite host for hibernation, and as many as fourteen mites have been found under a single bud scale. We have found no mites of this species in hibernation on prune or pear, and it appears that hibernation on these plants is relatively uncommon.

As the buds are swelling in the spring, the mites become active, and may be found crawling over the developing buds and adjacent stems. The mites overrun the unfolding leaves, and reproduction begins at an early date. Young mites have been found on apple at Corvallis as early as May 3, and all stages of the mites may be found on the foliage throughout the summer. With the approach of cold weather in late fall, the mites again seek hibernation quarters.

CONTROL

We have found that sulfur, either as a liquid or dust application, gives good results during the summer months when the mites are exposed on the foliage. Because of the protected position of the mites in hibernation, mid-winter sprays would probably have little or no effect. The standard sulfur sprays as applied just after the buds burst in the spring should give good results, providing no infested trees are left untreated in the immediate vicinity of the orchard. Only in an occasional orchard has this pest become sufficiently destructive to require special control measures.

[16]Brittain, W. H., Proc. Ent. Soc. British Columbia, No. 4, N. S., page 18, 1914.

[17]O'Gara, P. J., Science, N. S., 36, pp. 835, 836, 1912.

TREE CRICKETS

By B. B. Fulton

Growers of raspberries and loganberries are often annoyed by the splitting or breaking of many of the canes, due to the oviposition punctures of tree crickets. If the plants are examined at the point of fracture, there will usually be found on one side of the cane a number of small holes entering the pith, and placed close together in a row running lengthwise of the stem. The weakened condition of the woody tissue at this point causes the cane to split or break the first time it is subject to some unusual stress.

The oviposition punctures are about the size of an ordinary pin hole and the intervals separating them in the row are about the width of one hole. Each puncture contains an elongated yellowish-white egg about one-eighth of an inch long. The eggs are imbedded in the pith and extend across it in a slanting direction.

Egg punctures sometimes become points of infection for the raspberry cane blight fungus, which is known to attack the plant through any form of wound. In this way the tree crickets may be indirectly responsible for the spread of the disease. In many berry plantings tree cricket punctures are by far the most common form of wound to be found in the canes.

Fig. 33. Tree cricket oviposition punctures in cane. Adult male.

LIFE-HISTORY

The eggs remain in the plants over winter and hatch in June. The slender white crickets crawl up the stem to the foliage, where they spend the main part of their existence. They feed to some extent on the foliage and complete their diet by devouring small insects such as plant lice. The tree crickets mature in August and from then until autumn the broad-winged males can be heard singing during the night. The narrow-winged females spend most of the night boring holes in the canes and depositing eggs.

CONTROL

If tree crickets become so numerous in a planting that control measures seem advisable, they can be held in check by cutting out and burning any canes which are found to contain eggs. This can be done in the fall or spring, on the regular dates for training up and thinning out. Since the same method of control is used against the crown-borer, it can easily be extended to include tree crickets.

GENERAL INSECT NOTES

THE SHOT-HOLE BORER

Because of its unusual prevalence and injury during the past three seasons, the shot-hole borer *(Xyleborus dispar)* has been the occasion of no little concern on the part of orchardists. All varieties of trees have suffered, though the reports of injury to prune and pear have been most frequent. Three-, six-, and seven-year-old trees have probably been most generally and heavily injured, though all ages of trees, including the older bearing orchards have been attacked.

In the season of 1919, particularly, in reporting on the outbreak on the younger trees, growers would state that the trees appeared vigorous in the spring and grew thriftily until May. Then, following a brief drouth, the trees appeared sickly and devitalized, and an examination disclosed the presence of the borer. An interesting observation in this connection was that in the majority of the young orchards the attack commenced at the north side of the tree, where the cambium and sappy area is thickest, and was, in fact, largely confined to this area.

Exhaustive studies [18] carried on at the Oregon Station established the fact that the shot-hole borer is attracted to, and breeds successfully in only devitalized trees affected with sour sap. The wholesale attack by this borer during the past few years is due to the lack of vigor in the trees. This lack of vigor has resulted from a combination of adverse climatic factors. These are described and discussed under their proper headings elsewhere in this report. These factors constitute the initial cause for the wholesale devitalization of orchards or of the individual trees. Orchards and individual trees reacted differently, but it may be stated finally that in no case brought to our attention has the shot-hole borer been the initial offender or successfully attacked a healthy tree. The borers occur rather as a secondary pest following the initial devitalization of the tree from some other cause.

Discover the initial cause of the trouble if possible, and use every reasonable means to revitalize the tree by better cultivation, drainage, irrigation, fertilization, or whatever is most needed. In the spring paint infested trees, covering infested portions only, with the following:

Water	3 gallons
Soft soap or liquid fish oil soap	1 gallon
Crude carbolic acid	½ pint

Apply in spring when infestation is first observed, and repeat at weekly intervals until three treatments have been given.

[18] Wilson, H. F., The Shot Hole Borer of the Northwest Bien. Crop Pest and Hort. Rept., Ore. Exp. Sta., p. 97, 1913.

Fig. 34. Peach and prune twig miner, showing worm in green fruit.

THE PRUNE AND PEACH TWIG MINER

The prune and peach twig miner *(Anarsia lineotella)* has been recognized for years as a fairly serious pest of prunes and peaches because of the injury by the larvae in tunneling down the terminal twigs and killing them. It is no uncommon occurrence for the tops of young trees to be so seriously attacked as materially to change or destroy the shape of the trees. Older trees likewise suffer serious injury from this insect.

During 1919 and 1920 many reports were received and observations made of the serious attack of these larvae on young prune fruits. The larvae tunnel into the young fruit when it is about one-third the size of a mature cherry. Usually the worm enters near the stem end and tunnels about the forming fruit-pit within (Figure 34). This attack causes the infested fruit to drop. Numerous cases of excessively heavy fruit drop occurred in 1919 from this cause, which is a type of injury to be reckoned with.

The standard application for the control of the twig miner on prune and peach is commercial lime-sulfur applied at a strength of 1 to 8 just as the buds are swelling in the spring. Where this spray has been carefully applied, practically without exception, twig miner injury has been absent or a decidedly negligible factor.

BUD-WEEVILS

During the spring of 1920 numerous instances were brought to our attention of serious bud injury on newly-planted trees. Filbert trees were the most generally attacked, but pears, prunes, and other fruit trees were severely injured in an occasional planting.

The injury consisted generally in a gouging out of the heart of the swelling bud. Often the entire leafy tissue of the bud was devoured. The attack was usually progressive and new buds as they developed and attempted to open were in turn cut off or the heart eaten out.

In by far the majority of cases observed or called to our attention the injury was caused by the bud-weevils. In a few cases climbing cutworms were responsible for the destruction of the buds. The bud-weevils occur as rather small, grayish or brown and gray mottled snout beetles. They are fairly sluggish in their movements and tend to drop and feign death when disturbed. A careful examination of these weevils reveals the fact that the majority of our forms cannot fly.

Control. Protect the young trees from bud injury in the spring by the use of mechanical protectors placed about the trunk of the tree to prevent the weevils or cutworms climbing up to the limbs. Commercial mechanical protectors may be used; bands of tree tanglefoot about one-fourth inch wide serve as an effective barrier; cotton batting protectors are also effective. In applying cotton protectors obtain the cotton batting and cut in strips about five inches wide. The strips should be long enough to encircle the tree and lap slightly. Tie the band of cotton at the lower edge. Grasp the upper edge and pull or turn down over the lower, tied edge. This will form a fluffy, funnel-like barrier very effective except when wet.

THE RASPBERRY SAWFLY

The raspberry sawfly *(Monophadnoides rubi)* occurred in unusual numbers in 1919, causing a heavy defoliation of loganberries and raspberries in portions of Lane county and southern Washington county. The larva is greenish white, approximating in color the undersurface of the foliage of the raspberry. The body is covered with spiny tubercles. The adult is a medium-sized, robust, wasp-like sawfly. The adults are present in the spring during blossoming time. They deposit eggs within the tissue of the leaf. The larvae on hatching feed on the undersurface of the foliage, eating out small, shot-hole-like preforations in the leaf.

As they increase in size the feeding holes likewise increase in dimension, and defoliation rapidly develops. Spray tests demonstrate that applications of arsenate of lead, one pound to twenty-five gallons of water, applied just after blossoming has ceased, will effectually check this trouble. Apply the material as an underspray to the lower surface of the foliage.

THE BLACK GOOSEBERRY BORER

The black gooseberry borer *(Xylocrius cerebratus, X. agussizzi)* was found doing serious injury to commercial gooseberry plantings in the red hill lands of Polk county about seven miles northwest of Salem. This borer was first reported as injuring plants in 1898, when Dr. Fletcher of Canada noted it in British Columbia boring in the stems and roots of gooseberry plants which had been imported from Salem, Oregon. More recently it has been reported injuring gooseberries in California.

The adult beetles are about one-half inch long and dull black in color, the wing-covers being roughened. They appear generally in late summer and deposit eggs on the stems of the gooseberry. Undoubtedly the life-history may vary, as adult beetles were collected in the tunnels in the roots of gooseberry this spring—during April. The larvae, on hatching from the eggs in the fall, tunnel into the stems and bore downwards into the roots. They mature the following summer and transform again to adult beetles.

Control. The only method known at present is to cut out infested bushes and burn them. From present indications the pest promises to be a serious menace to commercial gooseberry plantings. A precautionary measure strongly advised is, in making new plantings, to examine the nursery stock very carefully for any indications of the presence of the borer. Where found, it is advisable to condemn the entire lot.

The asparagus beetle *(Crioceris asparagi* Linn*)* was first sent in from the trucking section of Multnomah county near Gresham in 1916. The pest was serious in limited areas trucked by the Japanese in 1918, and is apparently fairly well spread through the district now, causing considerable losses to asparagus growers.

Effective control[19] measures are known and may be had upon application to the College. It is assumed that they are not of sufficient general interest to warrant the lengthy discussion necessary in this report.

THE BEAN LADYBIRD

Beans showing the typical injury of the bean ladybird *(Epilachna corrupta* Meuls*)*, with accompanying larvae that were likewise seemingly typical of this insect, were received from Washington county in 1918. Beans showing similar injury were received from Linn county in 1919 and again from Washington county in 1920. So far, we have been unable to rear or obtain adults and thus be positive of the pest doing the injury.

THE CARROT BEETLE

The carrot beetle attacks sunflowers. Serious injury to the roots of sunflowers by the carrot beetle *(Lygus gibbosus)* was reported from Morrow county this summer. The adult beetles in great numbers tunneled into the surface soil about the roots of the sunflower, cutting off and devouring the roots and killing the sunflower plants. While local in its spread, the possibilities of this beetle as a pest of sunflowers planted for silage are worthy of note.

The beetles breed in humus and decay. Compost and manure piles are particularly a favorable place for the development of the grubs. Remedial measures against the adults promise little. Seek out and destroy or remove the breeding place of the grubs where possible.

[19]Write the United States Department of Agriculture for Farmers' Bulletin 837 on Asparagus Beetles, or to the Oregon Agricultural College Experiment Station.

MELOIDAE

Nearly every year reports of injury to corn and potatoes by blister beetles are sent in from Eastern Oregon. Usually the offender is either *Epicauta pardalis* Lec. or *E. puncticollis* Mann.

In 1911 and 1918, during May, serious injury to alfalfa was reported from Morrow county near Heppner by a large green blister beetle, *Cantharis cyanipennis* Say. As is characteristic of this family, the beetles suddenly appear in countless numbers from nowhere apparently. They show a marked preference for alfalfa, and soon destroy a field.

Blister beetles are elongate, narrow beetles, with flexible wing covers, a distinct neck region and a small rounded head. Where present in numbers there is evident a distinct, repulsive odor.

Poison spray applications of lead arsenate or paris green will kill the beetles where they feed on the sprayed foliage, but spraying is seldom practicable for blister beetles under field conditions. Pile windrows of straw along the windward side of the infested fields. After dusk fire the straw, and, provided with long sweeps, walk back and forth across the field sweeping the tops of the plants, and thus drive the beetles with the wind into the burning straw.

Part III

Report

of the

Department of Botany and Plant Pathology

WOOD DECAY IN ORCHARD TREES IN OREGON

By S. M. Zeller

The productive longevity of orchard trees in Oregon is of interest because of the prominent place orchard culture holds among the industries of the State. It is becoming more and more apparent that wood decay is the most severe factor which leads to early senility of productive trees. The common impression is that the prune and peach, for instance, are short-lived trees, while other trees will live to a very old age. On the contrary, W. W. Thomas, a student of this subject in California, reports a peach tree over fifty years of age and still in good producing condition because it has been given good care. Mr. Earl Pearcy, horticulturist and fruit inspector of wide experience in the State, has stated (Better Fruit, March, 1919,) in quite emphatic terms that it is wood decay that so often limits the productive period of prune trees to a comparatively few years. He shows a prune tree with sound heart which, under care, is vigorous at forty-two years of age. In company with H. P. Barss, Plant Pathologist at the Oregon Experiment Station, Mr. Pearcy in 1918 made an inspection of a number of prune orchards in Oregon to estimate the influence of wood decay on the aging of trees. They found innumerable instances in trees over twelve years old where the rotten tissues had so far encroached upon the vital portions of the wood as to cut down the productive vitality of the tree. Trees suffering from serious decay of trunk and framework can do little more than maintain the life processes, and from such trees the orchardist should expect in excess of this nothing but the most meager fruit production. It is of the greatest importance to the orchardist that his trees maintain as long as possible a high degree of vigor and productiveness. There are many reasons, therefore, why measures should be taken to prevent wood decay in orchards. Some of these reasons are pointed out in the following paragraphs.

NEED FOR WOOD DECAY PREVENTION

(1) **Wood-Rotting Fungi Are Prevalent in Oregon.** The decay of wood is not caused by old age or by exposure to the action of atmospheric constituents, but is produced by the digestive effects of certain fungi that live on wood tissues. Many different kinds of organisms causing wood decay are very prevalent in the orchards, wood-lots, and forests of Oregon and many of the forest or wood-lot fungi infest the wood of fruit trees. Some of the organisms which attack the wood of coniferous as well as deciduous trees of forests and wood-lots become very serious in orchard trees. In Western Oregon the fungi causing the most serious decay of cherry and pomaceous fruit trees are usually found on deciduous trees of the forest, while the most prevalent and extremely serious ones causing decay of peach and prune wood are usually found on wood of cone-bearing trees. The most serious organisms causing decay of cherry wood are *Irpex lacteus*, *Polystictus versicolor* and *P. hirsutus*, while the one serious wood rot of apple and pear is *Polystictus versicolor*. In peach and prune orchards the serious wood-rotting forms are named in the order of their prevalence: *Trametes carnea*, *Lenzites saepiaria*, *Fomes pinicola*, *Stereum hirsutum* and many others. In an orchard survey made by the writer, out of a total of 819 prune and peach trees showing heart rot 609, or 74.4%, were decayed by the pink-bracket fungus, *Trametes carnea*. This is by far the most serious of all wood-rotting fungi in the orchards of Oregon.

The prevalence of wood decay in orchards is sure to be associated with the prevalence of large wounds on the trees. Any exposed wood surface of considerable area is sure to become a seat of infection if it remains untreated. Out of a survey of 929 prune and peach trees which showed only ordinary care there were 844 trees having pruning cuts or

other wounds over two inches in diameter. Of the 929 trees examined there were 819 showing positive evidence of heart rot and these were all trees having wounds over two inches in diameter. That is, 97% of the trees with large wounds were found to be decayed. In orchards where wounds show careful treatment the percentage of visible wood-decay infection seldom exceeds 3%.

(2) **Oregon Conditions Favor Wood Decay.** The climatic conditions in Oregon are very favorable to the development of the organisms causing wood decay. There are three conditions which greatly favor the beginning of wood decay. These are an exposed wood surface, a mild fall, winter, or spring temperature, together with sufficient water on the wood surface for the spores to germinate. After the spores have germinated and the fungus has entered the wood the necessary conditions are just enough water in the wood to support active growth but not enough to crowd out the air necessary for the fungus. In Western Oregon, at least, conditions favorable to wood decay are too consistently fulfilled. We usually have mild temperatures and high humidity of the atmosphere combined with intermittent rainfall, which keeps the surface of the wounds moist enough for spore germination. By fall the long, dry summer has depleted the heart wood of any excess moisture which might crowd out the air. Thus when a tree passes into a dormant condition its wood is in a fit state for the rapid progress of decay if the fungus has once gained an entrance. Most orchard trees have been forced to grow rapidly. The wood of such trees is light and porous and it has been demonstrated that such wood decays much more readily than heavy, slow-growing wood.

(3) **Devitalized Trees Are Particularly Susceptible.** Winter injury to the bark and wood of trees, extended drouth periods, poor drainage, and other poor soil conditions have their devitalizing effects upon trees, as shown by early leaf drop, defective sap flow and "die-back" of the branches. This results in exposed dead wood and such a balance of water and air in the wood as to invite rapid growth of wood-inhabiting fungi.

(4) **Results of Wood Decay Are Deleterious.** There are many deleterious results of wood decay. It is first a source of weakness to the framework of an affected tree. A tree may have been so pruned that its scaffold branches bear a relation to each other such as to produce the strongest type of tree, yet decay of the wood in such a structure becomes very serious when heavy crops are borne or strong windstorms occur. Figure 35 shows the result of heart weakness in the lower crotch region of a prune tree.

We are often asked whether the fungi causing the disintegration of wood actually attack the living sap wood. We are sure that some of them do, although it seems necessary for them to have an exposed surface of dead wood in order to get a start. It has been found that *Polystictus versicolor*, which is the usual cause of decay of apple wood, frequently spreads much more than two feet a year in the living wood of the hardy catalpa. We have found many instances where a similar invasion of sap wood doubtless exists in orchard trees, especially peach and prune.

The presence of decayed wood in a tree trunk has a peculiar influence upon the living wood surrounding that decayed portion. In nearly all of the vessels which conduct the sap in the living wood may be found peculiar growths, called tyloses, which in sufficient numbers nearly stop the flow of sap through these vessels. Where a thin layer of living sap wood is found surrounding a decayed heart in peach or prune trunks these growths are fairly numerous in wood two and three years of age. Such a condition surely cuts down materially the conduction of water in the small portion of living wood left for this purpose. Thus, it is impossible for a tree having any great quantity of decayed wood in its trunk to conduct enough water during our hot, dry summers to support adequately its

leaf surface and crop of fruit. It would not be surprising if this were found to be one of the great contributory causes for such so-called "physiological diseases" as "prune leaf-roll," "June drop" of fruit, and the early yellowing and dropping of prune leaves.

The encroachment of decay upon the sap wood also cuts down the increment of productive wood as well as the productive longevity of the tree, as pointed out above. The permanent success of future crops from Oregon orchards depends upon the retention of old trees of great vitality and stability. Trees devitalized by internal decay are more susceptible to various fungous diseases, and observation has revealed that they are also less able to withstand severe winters.

(5) **Prevention of Wood Decay Is Especially Urgent Now.** A discussion of the means of prevention of wood decay is urgent and timely now because of the vast amount of injury in orchards of Oregon due to the December, 1919, freeze, discussed elsewhere in this report by W. S. Brown. The freeze was instrumental in exposing a great deal of wood where bark was killed on trunks and branches and around cankers and other wounds where the bark seemed to be extremely susceptible to frost injury. Growers must remember that all such wounds are exposed to infection

Fig. 35. Prune tree showing weakness in the crotch due to wood decay. Such trees break in strong winds or under heavy crops.

Fig. 36. An illustration of improper pruning of peach. Notice the long stub of dead wood and bark, and the fruiting body of the heart rot fungus (Fomes pinicola).

by wood-rotting fungi. It has also long been known that the black wood, known as "black heart," caused by low temperatures, is very susceptible to decay. The freeze, furthermore, produced much dead wood in the tops of trees, giving a general "die-back" effect. Such dead branches, as well as "sun-scalded" limbs, should be trimmed back to living wood. If not cleaned out, they will serve as seats for wood-decay infection.

In this connection it might be stated that such winter-injured bark and twigs are very susceptible to attack by the common "die-back" organisms, known as *Cytospora*. There are three species of these organisms prevalent in the orchards of Western Oregon. They may often be recognized by tiny red or white coils of spores coming from small pustules in the bark. Where these fungi are found the infected parts should be trimmed back some distance into sound wood, for these fungi do invade the healthy tissues during the dormant period of the tree. The trimmings should be burned.

The above-mentioned types of winter injury, which are so common now in Oregon orchards, should be taken as a warning for the orchardist to put forth every effort at once to prevent the entrance of wood-destroying fungi.

PREVENTIVE MEASURES

Among the measures which should always be taken to prevent wood decay are the following:

(1) Young trees should be so pruned that large cuts will be reduced to the minimum in future pruning operations.

(2) In older trees all pruning cuts of any size should be made close to the parent branch or trunk so that the bark will not die back from the cut and leave a projecting stub of dead wood. Figure 17 shows such improper pruning. It is usually a source of infection, such as shown in this photograph.

(3) Wounds by orcharding machinery should be avoided.

(4) All dead wood should be trimmed out.

(5) Dead bark and rough portions of cankers and other wounds should be cleaned away.

(6) All pruning and accidental wounds should be treated with an antiseptic after they have been disinfected by the removal of all rough portions and all indications of infection.

ANTISEPTICS FOR WOUNDS

There are many antiseptics for tree wounds which have been recommended and applied with various degrees of satisfaction. The preparations used for covering wounds may be grouped as "air-tight" or "air-porous" coverings. Asphalts, lead paints, and grafting waxes are sometimes used as "air-tight" coverings, while some coal-tar products and bordeaux paste are examples of the "air-porous" coverings. There have been objections to both forms of wound dressings. Volck's (Cal. Com. Hort., Monthly Bul. 6:80-89, 1917) objection to the "air-tight" covering is that the sap pressure back of such a coating will rupture it and there will be enough of the sap retained behind the coat to keep the wood moist and to insure infection by wood-rotting fungi. Bordeaux paste is the one "air-porous" covering which meets with the greatest approval. The one objection to this material is that it is gradually weathered away and its application must be repeated annually.

For some time the plant pathologists at the Oregon Experiment Station have been recommending the use of bordeaux paste as an antiseptic for tree wounds. The commercial bordeaux pastes, or bordeaux dust made up as a smooth paint by mixing with water, furnish the most practicable and most easily prepared pastes. However, if the grower prefers to mix his own paste the following formula may be of service:

FORMULA FOR BORDEAUX PASTE

Bluestone Solution—Dissolve 1½ lbs. of bluestone (copper sulfate or blue vitriol) in one gallon of water in a wooden, earthenware or glass vessel. This is best done by suspending the chemical in a bag of loosely woven cloth, or burlap, at the top of the water, or by pounding the lumps into small bits and dissolving by the use of hot water. This solution attacks metals (except copper) very actively.

Lime Paste—Slake three pounds of quicklime with one gallon of water, in the ordinary manner.

Mix in Equal Parts—When the lime is cool enough, equal parts of the bluestone solution and the lime paste should be mixed together thoroughly. Mix only enough at one time for a day's use. Apply like whitewash with a brush. The stock bluestone solution and stock supply of slaked lime can be kept indefinitely if not mixed together, provided water is added from time to time, to keep the solution up to the original volume.

If bordeaux paste is used alone its application should be repeated every fall.

In a recent communication Professor H. S. Fawcett, of the California Citrus Experiment Station informs me that in Southern California they have found bordeaux paste to be better than other wound coverings tried there. Where grafting wax, for example, was used as a complete covering for large winter-injury wounds there was much more subsequent heart rot apparent than in similar cases where bordeaux paste was used. Fawcett says: "The healing of the cambium was better and more rapid under the grafting wax than under the bordeaux, but this temporary advantage was many times counteracted later by the more rapid development of the rot in the wood."

We believe that Volck has devised a combination which will prove very satisfactory for those that desire in addition to an "air-porous" covering over the exposed wood an "air-tight" covering over the cambium to hasten the initial healing. He has recommended the use of a combination of asphaltum and paraffin for the treatment of the cut bark, lapping it over the cambium and edge of the wood, with bordeaux paste and copper tacks or nails as antiseptics for the wood. The asphaltum-paraffin wax is made by melting together and thoroughly mixing eight parts of asphaltum to two parts of paraffin by weight. It is applied to the margin of a large wound so that it covers the cut edge of the bark and laps over onto the sap wood enough to protect the bark from drying out until growth begins to cover the wood. This coating is applied warm immediately after the cut is made. The exposed wood is then coated with bordeaux paste and driven full of copper nails. The bordeaux paste contains enough copper in a soluble form so that it gives temporary prevention of wood-decay infection until the copper nails or tacks which, through their gradual solution by the acids of the wood, produce a more permanent antiseptic condition. It is well in this treatment, Volck suggests, to repeat the application of bordeaux paste to fill up the cracks which later develop in the wood as it dries until the action of the copper nails has become effective. On very large wounds Volck recommends the use of copper-wire screen fastened down to the wood by copper nails. The bordeaux paste sticks much better to such a screened surface.

EXPERIMENTAL WORK

To test out the effectiveness of copper nails as an antiseptic against wood-decaying organisms a few artificial experiments have been conducted by the writer in the Plant Pathological laboratory at the Oregon Experiment Station. Blocks of apple wood approximately two inches long were stripped of bark. Copper harness rivets of various lengths were driven into the wood. After the blocks were sterilized some were inoculated immediately, others after three, six, nine months, etc. They

were inoculated with *Lenzites saepiaria*, a fungus which destroys apple wood with comparative rapidity. After those immediately inoculated had been subjected to the action of the fungus for ten months some of them were split open for examination. It was found that the blocks were decayed by the action of the fungus in all portions except that within about three-sixteenths of an inch from the nail. The sound portion of the wood extended to the greatest distance from the nail in the direction of the wood grain. Where the copper was allowed to diffuse for three months before the wood was inoculated there is no indication of decay within one-eighth of an inch of the nail head. In those blocks inoculated six and nine months after the nails were driven the disintegration of the wood is not yet sufficient for detection in any portion of the blocks, but the growth of the fungus on the surface of the blocks leads us to believe that the poisonous principle from the copper has penetrated lengthwise into the wood for a distance of at least 1½ inches. This is indicated by the appearance of a definite spot about the size of the nail head free from fungous growth on the opposite end of each block from the nail head, as is clearly shown in Fig. 37, (B) and (D). This photograph shows two such blocks sawed in two and placed so that both ends of the blocks are in view. (A) shows the end of a block with the nail and (B) shows the other end of the same block with the spot corresponding to the nail head and in which there is no growth of the white fungus. (C) and (D) represent the same two views of another block. This indicates that there is a column of poisoned wood below the nail head into which the fungus will not grow and thus it would seem that short, broad-headed copper tacks should be as effective as long nails. Short tacks would also be more desirable, for they would not have as great a tendency to split the wood.

We believe that the results of our laboratory experiments already show that copper nails will render the wood poisonous enough to prohibit the growth of certain wood-destroying fungi, but there are many other angles of the question which are still under investigation. For instance, we do not know how far apart the nails can be driven and yet insure complete antiseptic conditions nor whether the poisonous principle will penetrate equally well up and down from nails driven in the side of a canker. Such information is necessary before it can be ascertained how far apart it would be advisable to drive rows of nails at right angles across cankers.

Experiments are also under way to test out the efficiency of bordeaux paste in this connection. It is also desirable that certain coal-tar products

Fig. 37. The effect of driving copper nails into apple wood. A and C show the copper nail heads. B and D are the opposite ends of the same blocks. Notice the dark spots where the white fungus growth has been inhibited showing how the antiseptic substance from the copper is carried lengthwise in the wood.

be tested out as antiseptics for wounds. Some of the coal-tar products, sold under various trade names, such as carbolineum, creolineum, carbosota, etc., may eventually prove to be of service as antiseptics for wounds, if used with care. There is, perhaps, a chance that one of the many brands of carbolineum, for instance, may ultimately prove useful as a dressing, for wounds in general, or possibly even show merit for the treatment of cankers like those produced by gummosis in stone fruit trees. But the probable value of such materials and their safety in contact with living tissues is now open to serious question, and before the grower ventures to place his trust in any brand he should be certain that it has been thoroughly tested experimentally under conditions similar to his own for the particular use he has in mind. It is common knowledge that many brands of carbolineum are very injurious to the living tissues of bark and newly forming wood when used as a wound dressing, and one well-known foreign plant pathologist has said regarding carbolineum that "its recommendation as a remedy for chronic gummy exudations (gummosis) is based at least upon self-delusion if not the exigencies of advertising."

STATUS OF WOUND ANTISEPSIS

Although at the present stage of our investigations it is impossible to make as complete recommendations as we hope to be able to make in the near future, it seems from present evidence safe to assert:

(1) That bordeaux paste will prove to be an effective "air-porous" dressing for wounds if applied at least each fall.

(2) That more permanence may be added to the antiseptic properties of the treated wood if copper nails or tacks are used to supplement the application of bordeaux paste.

(3) That there is doubtless merit in Volck's method of using a mixture of asphalt and paraffin over the bark and cambium, in addition to the copper nails and bordeaux paste on the wood. This method is surely preferable to any other known to us for the treatment of large wounds. Perhaps bordeaux paste used alone is sufficient for small wounds.

A SERIOUS NEMATODE DISEASE OF STRAWBERRY AND CLOVER IN OREGON

By M. B. McKay

There has recently come to the attention of the laboratory of plant pathology a serious outbreak of a disease of strawberry and clover caused by the leaf- and stem-infesting nematode, *Tylenchus dipsaci* (Kühn) Bastian. This pest has been known as a serious menace to the growth of a variety of crops in Europe, Australia, and southern Africa[1] and during recent years it has been found causing severe damage to a number of crops in America, especially in the northwest states.[2] Since it appears to be getting established in some localities in Oregon, it is especially desirable that Oregon growers become acquainted with its nature and control, and realize to the fullest extent the seriousness of the pest to the end that it may be stamped out, or at least checked in its spread, as soon as possible. It is the purpose now to acquaint the grower with the pest, so that it may be recognized more readily, to list the crops which have been attacked by it in the past, and to outline the methods of control that have been recommended.

EFFECT OF THE DISEASE ON ITS HOST PLANTS

Unlike a number of other nematode diseases such as the common root-knot nematode or the sugar-beet nematode, this pest works not so much in the roots, but mainly in the stems and leaves of the plants. In strawberries it produces the most distinct and noticeable symptoms in the form of swellings or galls in any portions of the stems, leaf petioles, or runners, and characteristic distortions of the leaflets, which become crinkled, misshapen, and dwarfed in size (Plate X). The stem at the base of the fruit is often distinctly swollen and distorted, and when badly attacked the whole plant appears crunched down, crinkled, and dwarfed. In clover the infested stems are rather uniformly swollen throughout their length and are generally much shortened (Plate XI), thus causing the affected plants to be stunted as compared with unaffected plants. They turn yellow to brown in color due the premature death of the affected stems. Since the pest naturally spreads more readily to the plants nearest by, such plants are often seen occurring in well-defined spots in the field. On other host plants the nematode in general is said[1] to produce characteristic distortions and usually yellow to brown longitudinal discolorations which indicate the presence of the parasite. In hyacinths the disease is known as the "ring disease," due to the fact that the nematode migrates from the leaves into the bulb, thus affecting entire scales, which become discolored. Affected bulbs when cut in cross-section may show one or more of these characteristic rings. In hyacinths, onions, and other bulbous crops, affected leaves are not noticeably swollen or distorted, but show yellow longitudinal streaks. Such leaves finally wilt and die prematurely.

PLANTS AFFECTED BY THE DISEASE

In Oregon the disease has thus far been found occurring only on strawberry and red clover. In other parts of the United States or in foreign countries it has been authentically reported also on a large number

[1]Smith, Ralph H. 1919. A preliminary note concerning a serious nematode disease of red clover in the northwestern states. Jour. Econ. Ent. 12:460-462.

[2]Anonymous. 1916. An eelworm disease in the Pacific Northwest. United States Department of Agriculture, Office of Information. Mimeographed circular.

PLATE X

NEMATODE-INFESTED STRAWBERRY PLANTS FROM WESTERN OREGON.

The fruit stems and leaf petioles show characteristic swellings and the leaflets show typical crinkling and distortions due to the presence of the pest in the interior of the tissues. The insert shows a drawing of a group of the larvae in various stages of maturity and eggs of the nematode, considerably magnified, secured from diseased strawberry tissues.

of other plants. Altogether, it is known to attack upwards of one hundred species of plants, of which the following may be mentioned:

*Strawberry	*Rye	Phlox
*Clover	Potato	Plantain
Alfalfa	Hops	Spear grass
Pea	Turnip	Bindweed
Lupine	Flax	Primrose
Broad bean	*Onion	Buttercup
Kidney bean	Garlic	Sow thistle
Wheat	*Hyacinths	Penny cress
Oats	*Narcissus	Daisy
Barley	Forget-me-not	Teasel

Those which are marked with a star (*) have been found affected with the disease in the United States. The large list of plants which the pest is able to attack illustrates the importance of the disease and makes its control more difficult to accomplish.

CAUSE OF THE DISEASE

The disease is caused by the presence of thousands of small eelworms inside the stems or leaves. The irritation to the plants from the presence of these worms causes the formation of the crinkled areas or the gall-like developments of the stems. If a bit of the affected stem or leaf tissue is carefully torn apart in a small amount of water in a dish the white, thread-like, generally curved larvae may be seen actively moving about with eel-like movements. These are the larvae of the nematode *Tylenchus dipsaci* (Kühn) Bastian, and are about one-fiftieth of an inch long. These larvae are hatched directly from eggs and reach maturity in about four weeks, so that several generations may be produced during one season. Each female may produce a large number of eggs. This fact, with the short life cycle, makes possible a very rapid increase in the number of individuals.

DISTRIBUTION OF THE DISEASE

In Oregon on strawberries the disease was first found by Professor A. L. Lovett, at Corvallis in 1916, in a variety-testing plot conducted by the Horticultural department of the Agricultural College. Plants for this plot had been secured from many different localities in the United States, and it was not possible to check back and determine definitely from what locality the pest had been introduced. It is possible, however, that it may have come from a grower in Northern California. After a few years the original bed was abandoned and a new one started from selected young plants. The pest finally became quite serious on this second bed and in 1920, for this and other reasons, it was abandoned and a third one started. In the variety, Ettersburg, a small percentage of the young plants are already, a few months after transplanting, showing characteristic injury from the nematode disease. This illustrates the danger that is run in starting a new strawberry planting from an infested bed. It also shows that the pest when once established will readily persist unless very definite steps are taken to prevent its continued existence. During 1920 several badly diseased strawberry plants were received from different growers at Tsilcoos, Canary, and Ada, all in Lane county, and from one farm just across the line in Douglas county. These growers had all received their original strawberry plants directly or indirectly from one grower. It is very likely that the pest was carried to these different farms in the young plants thus secured from this central place. Byars[3] reports having seen diseased strawberry plants sent in 1915 from Port Terrace. Probably Point Terrace is meant, as the former name does not occur in the postal guide, while Point Terrace is within a few miles of the region now known to be well infested.

[3] ———. 1920. A nematode disease of red clover and strawberry in the Pacific Northwest. Pytopathology 10:91-95. 2 pls.

PLATE XI

NEMATODE-INFESTED CLOVER PLANTS FROM WESTERN OREGON.

The infested stems are much shorter than the uninfested ones on the same plant. This results in giving badly diseased plants a stunted appearance. Infested stems are also considerably and rather uniformly swollen as illustrated by the one single stem photographed alone.

On clover in Oregon the pest was first seen by Professor A. L. Lovett in 1915 on specimens from Redmond, an irrigated region. Since then, several collections were made of it in 1920 in the Tsilcoos-Canary-Ada, non-irrigated region, where the pest was also so abundant on strawberries. Thus the pest is known to occur and to do much damage in both irrigated and non-irrigated regions. Judging from its action in western Lane county and at Corvallis, conditions seem to be particularly favorable to its reproduction and spread throughout Western Oregon.

In other parts of the United States the disease has been found at Edgerton, Kansas;[4] Bellingham, Washington;[5] and in the irrigated sections of Eastern Washington, Southern Idaho, and Northern Utah.[1] It has also occurred as a serious pest in certain parts of Europe, Australia, New Zealand, and South Africa.

METHODS OF PREVENTION AND CONTROL

The chief method of control so far recommended consists in the proper rotation of the land with non-susceptible crops combined with sanitary measures. By planting infested fields for two or preferably three successive years with non-susceptible crops the pest will be starved out to such an extent that little infestation is apt to occur when the land is again planted the following year with a susceptible crop. To make the rotation effective clean cultivation should be rigidly practiced so that no weeds or volunteer plants will remain alive and harbor the pest. For this purpose the crop should preferably be grown in rows. Some of the plants, which may be suggested for use as rotation crops on infested land and which are more or less adapted to the region are: corn, cowpeas, soy beans, millets, sunflowers, tomatoes, asparagus, cabbage, broccoli, lettuce, cantaloupes, and celery. Almost any other crop not listed above as being subject to the disease could also be used.

As soon as the presence of the pest in the Coast region of Lane county was determined, the State Commission of Horticulture, through the leadership of Mr. C. E. Stewart of Cottage Grove, fruit inspector of Lane county, realizing the increasing importance of strawberries in that region, began an active campaign to eradicate the pest if possible. Some badly-infested areas were plowed up entirely. In the case of light infection of some strawberry plantings an effort is being made to eliminate the disease by promptly roguing out all diseased plants as soon as discovered. It remains to be seen whether this method will prove as effective and feasible as is hoped. In the meantime growers are advised promptly to rogue out and destroy all infested strawberry plants. Because of the danger of carrying the pest in the soil about the plants, probably no strawberry plants should ever be distributed and used from an infested bed, even though the plants used show no visible infection. Very likely it was through this means that the pest has been established on so many farms in Oregon.

Some studies conducted on this nematode have suggested the existence of strains or races of the pest which become adapted to certain crops and do not readily attack other crops. It seems likely, however, that in Oregon the pest passes with little or no difficulty from strawberry to clover and vice versa, for in Western Oregon the nematode disease of strawberry and of clover occurs on each crop in the same locality and in some cases on the same farm. Also in one test recently conducted in the greenhouse at Corvallis where clover seed was planted in soil containing diseased strawberry plants, a large percentage of the young clover seedlings were affected by the nematode disease shortly after they emerged from the ground. These affected seedlings had a distinct gall-like swell-

[4]Bessey, Ernst A. 1914. Tylenchus dipsaci in the United States. Phytopathology 4:118.

[5]Byars, L. P. 1914. A destructive nematode introduced into the United States. (Abstract) Phytopathology 4:45-46.

ing of the stem near the bud area at the base of the petioles of the first leaves or cotyledons. From their appearance it seems that a number of these seedlings are so badly affected that they will not be able to survive long, while others, more lightly attacked, may ultimately attain to considerable size. It is too early, however, to predict the final extent of the injury to them. There is need for more extended tests to determine whether the strain of the nematode affecting strawberry and clover in this State passes readily to all crops known to be infested by it in other places.

The United States Department of Agriculture and the Idaho Agricultural Experiment Station are now conducting a cooperative study of this pest and very likely improved and additional control measures will result from this and other similar investigations.

PLATE XII

The results of the leaf-curl disease and the effects of proper spraying. Two Elberta trees side by side in the planting, the left hand one, sprayed with bordeaux once, has every leaf healthy; the other, not sprayed, has every leaf diseased.

PEACH LEAF-CURL CONTROL

By H. P. Barss

According to the 1920 report of the State Tax Commission there are still left, after the unprecedented freeze of December, 1919, over 2500 acres of peach trees in Oregon. The 1919 crop amounted to half a million bushels, valued at two-thirds of a million. Any disease, therefore, which, like leaf-curl, may quickly ruin an entire orchard must demand energetic attention on the part of the growers of the State. Although many of our peach orchards have been kept in fairly good condition by systematic spraying, yet year by year a larger number of them fall into a practically worthless state as a result of the uncontrolled effects of two diseases, peach leaf-curl and peach blight. Successful methods of control for these diseases were devised long ago, but in spite of efforts and intentions to apply the recommended methods many growers have seen their peach orchards deteriorate from bad to worse. In fact, so general and wide-spread over the State have been the destructive results of the leaf-curl

Fig. 38. Peach leaves affected with the fungus causing peach leaf-curl. Note the wrinkled and distorted tissues.

attacks from year to year that a series of experimental tests was begun some years ago by the Experiment Station to determine for Oregon conditions the best material to use for leaf-curl control and the time limits within which applications could be depended on to be effective. A brief survey of some of the results which should be encouraging to growers will be given later in this article. The tests indicate that it lies entirely within the power of Oregon peach growers to keep the damage from this disease down practically to zero.

CAUSE AND SYMPTOMS

The cause of the leaf-curl disease is a microscopic fungus *(Exoascus deformans)* which enters the leaves and sometimes the shoots just as they are emerging from the buds in early spring. It grows within the infected organs, causing the typical thickening and distortion well illustrated by the accompanying photograph. In mid-spring the diseased leaves show a rather whitish bloom on the surface, due to the discharge of millions of the microscopic spores of the fungus. These leaves then begin to turn brown and dry up. Their shrivelled remains often hang to the branches throughout the season.

Infections rarely if ever occur except at the very beginning of the growing season. There is some variation in the severity of attack from season to season, due largely to variations in weather conditions. Wet weather during the time when leaves and blossoms are emerging favors abundant infections, while dry weather has the opposite effect. Since wet weather is the predominant climatic characteristic at the time of year peach buds are unfolding in Oregon, heavy leaf-curl attacks are the rule rather than the exception.

Varieties differ considerably in their natural susceptibility to the disease and, depending on the weather, in some cases doubtless a difference in earliness will account for differences in severity of attack in certain seasons even among equally susceptible varieties. Observations show that the Elberta variety is probably the most highly susceptible of all varieties commonly grown, with some of the Clings, Columbia, and several other sorts also subject to very severe infection. The Salway and Muir are among the least susceptible, with the Crawfords slightly more subject to attack.

After the tender leaves have begun to grow out of the buds and opportunity for infection has occurred, spraying cannot prevent the development of the disease, even though its effects are not yet apparent, since the parasite is already inside the leaf tissues, where it is protected against contact with the spray. Innumerable failures to secure control have been due to the fact that growers, in putting on the spray, have so often waited till the leaf tips were emerging, when it was too late.

On the other hand, successful control of the disease cannot be obtained by spraying prematurely. It was discovered some years ago, for instance, that the fall sprays given in California for peach-blight control would not control the leaf-curl at the same time, and the experience in Oregon has been somewhat similar. For some unknown reason it appears that successful results can be safely anticipated only when the leaf-curl spray is applied after a period of fall rains has occurred.

The general effects of the disease on a tree are such as would be expected from the destruction of its foliage by any agency. The growth may be retarded or entirely checked and the crop reduced or eliminated. The reserve vitality of the tree is drained, first to support the infected leaves and then to replace them by new growth. As a result, the set of buds for the next year is weakened and the chances for a good crop the following year lost. Total infection of all new foliage early in the season is common, and when followed by a similar attack the next year and the year following, may be fatal to the tree.

PLATE XIII

Twig of the peach affected by peach leaf-curl fungus. Note the swollen and distorted branch, as well as the affected leaves.

INVESTIGATIONS

The spraying tests of which the results are very briefly summarized here were conducted in the pathological orchard in one corner of the Experiment Station farm at Corvallis during the seasons of 1916, 1917, and 1918. The work was carried on in the successive years under the direction of the writer by G. B. Posey, O. H. Elmer, and C. E. Owens. A continuation of these tests was begun by W. A. Smart in the fall of 1919, but the freeze of December of that year killed out the plantation. The earlier tests, however, brought out some very valuable information.

Comparisons of Different Fungicides. A glance at Table XIII gives a clear-cut idea of the comparative value of different materials tested. Several other varieties were included in the tests besides the Elberta; namely, Phillips Cling, Tuscan Cling, Heath Cling, Early Crawford, Late Crawford, Early Charlotte, Muir, and Salway. The results for all varieties and for the different years are in substantial agreement, but for this

TABLE XIII. SUMMARIZED RESULTS OF SPRAYING TESTS AT CORVALLIS FOR PEACH LEAF-CURL CONTROL

Seasons of 1916, 1917, and 1918; Elberta variety.

Material used and strength.	Years tested.	Average percentage of leaf curl.
		%
Bordeaux 6–6–50	'16, '17 '18	3
Sherwin-Williams Fungi-Bordo 12–50	'17, '18	11
Lime-sulfur 1–8	'16, '17, '18	19
Soluble sulfur 12–50	'17	40
Cresol 1–100	'18	62
Copper sulfate (Bluestone) 6–50	'16	72
Sealocide 1–15	'17, '18	97
Dusting sulfur 90–10	'17	100
Unsprayed check trees	'16, '17, '18	100

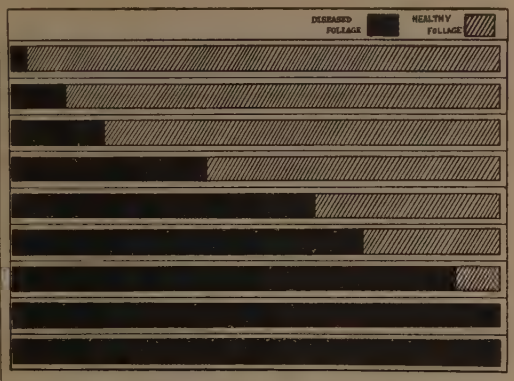


table the results on the Elberta were selected because it is admittedly our most susceptible variety and the relative degrees of effectiveness of the different fungicides stand out with the most striking distinctness.

Of all the materials tested none can compare in effectiveness with the standard, home-made, bordeaux mixture. The accompanying photographs of two Elberta trees standing side by side in the row, one sprayed with bordeaux and the other left unsprayed, illustrate what the spray will do. More often than not in the three years' tests the bordeaux-sprayed trees were absolutely free from any trace of leaf-curl, the occasional presence of the disease being attributable more easily to imperfect spraying than to any lack of effectiveness of the spray. Next in value, as might be expected, is a commercial dust bordeaux, which, however, for some unknown reason, never quite equalled the showing of its grandparent. In 1916 straight bluestone solution was tried out, but

although showing some effect proved a disappointment, doubtless on account of its solubility and consequent lack of permanence on the tree.

Lime-sulfur 1 to 8 (scale strength) showed a fairly successful average degree of control, but a study of the detailed data from all the tests and from observations over the State shows that for unexplained reasons lime-sulfur is erratic in its efficiency. At times it will result in control almost equal to bordeaux. At other times lime-sulfur-sprayed trees have shown a very high degree of leaf-curl infection, even up to 60 percent or more, when bordeaux applied by the same person, with the same outfit, and on the same day has exhibited its usual successful results. Possibly temperature relations at the infection period may have something to do with this peculiar irregularity in the success of lime-sulfur, since it is well-known that sulfur requires rather high temperatures for fungicidal efficiency. This may account for the total failure to get control by the use of the dusting sulfur and lead arsenate (90 to 10) combination. Soluble Sulfur in the single year's test gave entirely unsatisfactory results, although better than the dust.

Sherwin-Williams dry lime-sulfur (12 lbs. to 50 gals.) was also tested in 1917 and 1918, but did not equal the ordinary lime-sulfur, although displaying similar erratic results.

Compound solution of cresol (1 to 100) and Scalecide (1 to 15) proved to be practically useless.

Field Observations. In the spring of 1917, C. R. Hursh, then research assistant in Plant Pathology at the Experiment Station, took careful records in ten peach orchards near Salem, and in the spring of 1918 at the suggestion of the writer, Earl Pearcy, then fruit inspector in Douglas county, made a study of peach leaf-curl control in twenty-six orchards in the Umpqua Valley. The results of these field observations, together with the information secured from many growers by the writer, are in entire accord with the results of the test at Corvallis in establishing the high degree of effectiveness of bordeaux mixture, the importance of thoroughness of application, and the necessity of applying the spray sometime before the winter buds begin to break open, if successful control is to be insured.

Time of Application. For a good many years the general recommendations for leaf-curl control advised spraying just before the buds opened. In attempting to follow this advice closely, growers frequently waited too long until the buds had just started to open or else they met with weather conditions at the last minute which prevented them from getting the spray on in time, with the result in either case that the work was only a partial success, if not a complete failure. Along with tests of materials, therefore, the Experiment Station also tested various times of application. The experimental results, which are in accord with the data collected by Hursh and Pearcy, indicate clearly that it makes very little difference at what time during the winter the leaf-curl bordeaux spray is put on, provided it is applied before the infection period.

Pearcy's notes show very clearly that in Douglas county in 1918 the last week in February was too late for complete prevention of the disease in Elbertas and some of the Clings, although not for most other varieties, while control was nearly perfect for all varieties in orchards sprayed before the tenth of February.

A few years ago the Cornell Experiment Station showed that fall spraying would control leaf-curl in a satisfactory manner. Certain tests in California, however, have shown that in that state in some seasons, at least, a spray as late as the first of November was not always successful under the climatic conditions there existing. It has also been experienced in Oregon that early fall sprays for peach blight did not protect the trees against leaf-curl. No complete series of tests has been conducted in Oregon to determine just how early successful control may be secured

under our conditions. The studies along this line started in the fall of 1919 by W. A. Smart were obliterated by the freeze. In 1916, however, perfect control of the disease had been secured on Elbertas and other varieties at Corvallis from experimental applications made on November 27, 1915. Pearcy also reports successful results from sprays applied in November in Douglas county. It may be concluded with safety, therefore, that a bordeaux spray given at any time from the first of December until the fore part of February will give perfect control. It is impossible to say how much earlier or how much later it is safe to spray. It probably depends a good deal upon seasonal climatic conditions.

RECOMMENDATIONS

(1) For the control of peach leaf-curl use bordeaux mixture 6-6-50. Add soap or some other spreader if desired to increase the penetrating and covering power. Lime-sulphur sometimes gives excellent results but for unknown reasons is much less reliable than bordeaux.

(2) Apply the spray any time between the first of December and the first part of February. Do not wait until the leaf tips begin to show from the buds, as it may then be too late to secure control.

(3) Spray thoroughly so as to cover and protect every bud on the tree.

(4) Spray every season, for perfect control in one season will not necessarily prevent heavy infection the following season.

GOOSEBERRY MILDEW CONTROL

By C. E. Owens

While gooseberries have been grown in Oregon for many years, they have never been considered an important commercial crop until quite recently. Due to the development of the canning industry in this State during the last few years, an extensive demand for berries of various kinds has sprung up. Gooseberries are among the fruits which are now in large demand by the canneries, and more numerous and larger plantings of this fruit have been made during the last year or two than ever before. The gooseberry thrives in this section of the country and there seems to be no reason why it should not prove to be a profitable crop, providing it can be kept free from pests. The worst disease of the gooseberry known in the State is the powdery mildew. Some varieties are very susceptible to this disease and in bad years the loss of an entire crop may result unless the grower has taken the proper precautions. Fortunately this disease can be controlled at no great expense, so that the careful grower need have no fear of extensive losses from this source.

CAUSE AND SYMPTOMS

Gooseberry mildew is caused by a fungus, the scientific name of which is *Sphaerotheca mors-uvae*. The fungus appears first in the spring as a whitish, powdery or mealy growth on the young leaves, shoots, and fruits. If weather and other conditions are favorable for the spread and development of the disease, all the berries soon become covered

Fig. 39. Left, branch from unsprayed bush, badly mildewed; right, branch from sprayed bush, entirely free from mildew.

with the mildew and are a partial or total loss. As the season progresses, the whitish growth of mildew on the berries gradually turns dark brown or almost black. This change in color is due partly to the development of large numbers of minute, round, black spore-cases (perithecia) each containing several spores. The fungus may live over winter in two ways. The spores in the winter spore-cases mentioned above may survive the winter and on the breaking open of these cases in the spring the spores may infect the young leaves or fruits. On the other hand, parts of the fungus may become inbedded in the buds, and winter over in that protected place, ready to infect the leaves when they emerge in the spring. In the first instance, the spores are protected by the heavy wall of the spore-case, while in the second, the fine threads (mycelium) of the fungus are protected by the bud coverings.

EXPERIMENTAL CONTROL

In 1916 the Oregon Experiment Station decided to carry out a set of experiments to determine the best method of controlling gooseberry mildew under Oregon conditions. During the spring of 1916, Mr. G. B. Posey, who was on the Experiment Station staff at that time, tried out a number of spray materials on a plot of gooseberries on the Experiment Station grounds. He used lime-sulfur, "Atomic Sulfur," barium tetrasulfide, and bordeaux mixture. The results of these preliminary tests by Mr. Posey indicated that lime-sulfur was by far the best of the four sprays tried. Counts and estimates made at harvesting time showed 97 percent of clean fruits on bushes sprayed with lime-sulfur, whereas unsprayed bushes showed no clean fruit at all. Bushes sprayed with Atomic Sulfur had 79 percent clean fruit; those sprayed with bordeaux 61 percent, and those sprayed with barium tetrasulfide 52 percent clean fruit.

During the season of 1917, the writer continued the experimental work begun in 1916. Since lime-sulfur was the only one of the four sprays tried in 1916 which gave entirely satisfactory results, the other three were

Fig. 40. The proper stages for spraying: A. Time for the first spray—just as the leaves unfold. B. Time for the second spray—just before blossoms open. C. Time for the third spray—immediately after blossoming.

discontinued and the work with lime-sulfur was repeated. Sulfur-lead-arsenate dust (85 to 15) and iron sulfide mixture were also given a trial, the object being to find out if either of these well-known materials was equal to lime-sulfur for the control of gooseberry mildew. The results in 1917 gave further evidence of the efficacy of lime-sulfur in the control of this disease, the control being even more complete in some cases than in 1916. Of the other two materials used this season, the sulfur-arsenate dust proved almost equal to lime-sulfur, while the iron sulfide mixture was so much less effective that it cannot possibly be recommended.

In his experiments, Mr. Posey made three applications of the sprays during the season; the first as the leaves were emerging from the buds, the second just before the blossoms opened, and the third just after blossoming, as illustrated in the accompanying photograph.

In the experiments of 1917, the writer reduced the number of applications on certain plots to one, namely, the first. On other plots only the first two applications were made. The object was to ascertain the minimum number of applications which could be relied upon to give control. The results showed that the mildew on the less susceptible American varieties such as Oregon Champion, could be very satisfactorily controlled by one application of lime-sulfur, strength 1 to 15, applied when the leaves have partly emerged from the buds. On the more susceptible European varieties, as, for example, Industry, at least two applications are necessary for fairly good control and for complete control three applications seem desirable. As far as could be determined by this one season's work, two applications of the sulfur dust were about equal to one application of lime-sulfur, while two applications of the iron sulfide mixture spray were much less effective than the two dustings.

Fig. 41. This represents all the gooseberries from one sprayed bush. The pile on the left contains all the mildewed fruits on the bush, none of them heavily affected, while the pile on the right shows the perfectly clean fruit from the same bush. Note the very small percentage of loss. The unsprayed bushes in the same experiment had every berry badly mildewed.

RECOMMENDATIONS

Based on the results of the two seasons' experimental work just referred to, it seems certain that lime-sulfur is the best remedy for powdery mildew of gooseberries under Oregon conditions. Complete control should be obtained by not more than three applications of the spray, and under ordinary conditions one or two sprayings at exactly the right time should satisfactorily control the disease.

The following spray schedule is recommended:

(1) When the leaves are emerging from the buds, as shown in Figure 39A, lime-sulfur 1-25.

(2) Just before blossoming Figure 39B, lime-sulfur, 1-45.

(3) Just after blossoming, Figure 39C, lime-sulfur, 1-50.

The first application on the above schedule is the most important and should be put on at the proper time. If delayed beyond the time indicated, the disease may get a start such that it will be much more difficult to control with later sprays. But if the first spray is done thoroughly and at the right time, in all probability there will be little necessity for later applications unless the season is particularly favorable for the disease. The grower should keep a close watch, however, and if at any time the least sign of mildew appears, another spray should be applied immediately.

Thorough covering of every particle of foliage is essential to success. The grower will find that under some conditions a slight burning of the leaf edges may occur from the lime-sulfur, but the foliage quickly outgrows this effect.

Dusting with high-grade, specially prepared, dusting sulfur is a promising method, but will undoubtedly be most effective as the warm weather approaches, while lime-sulfur will do the work even in the cold weather which often prevails in early spring.

CYLINDROSPORIUM LEAF-SPOT OF PRUNE AND CHERRY

By H. P. Barss

In general the prune and cherry orchards of Oregon are not greatly troubled by diseases attacking the foliage. There are seasons, however, when in certain sections of the State considerable damage is experienced from the Cylindrosporium leaf-spot disease, which in severe attacks causes serious defoliation with consequent damage to crop, to tree growth, and to the setting of fruit buds for the following year. The principal losses from this disease have been reported from the Willamette Valley. Estimates indicate that probably at least $75,000 damage resulted from the attack of 1916 in this important fruit region. The next year, however, saw a practical disappearance of the disease even in the worst infested orchards, and little more was heard of the trouble until the 1920 growing season, when from many points not only in the Willamette Valley but as far east as Freewater and as far south as the Umpqua Valley reports of damage were again sent in to the Experiment Station. It is evident that orchardists should be on their guard and ready to combat the disease whenever conditions favoring an epidemic arise.

Fig. 42. On the left, leaf of sweet cherry affected by Cylindrosporium. On the right, leaf of Italian prune affected by Cylindrosporium.

CAUSE AND SYMPTOMS

The cause of the disease is a fungus, scientifically known as Cylindrosporium or Coccomyces, which lives over from one season to the next in the old foliage on the ground. In the spring the microscopic spores of the fungus are discharged from the old leaves and are carried by the air currents to the new foliage, which under favorable conditions becomes infected. From the spots which then appear on the new leaves an abundant new crop of spores is quickly produced, which may result in a rapid spread of the disease during the growing season or even in an epidemic.

When prune leaves are attacked early in the season small dead spots are produced and these often fall out of the leaf, leaving what is termed a "shot-hole" effect. The later infections on prune leaves, however, rarely

cause this perforation. The leaf then shows only small dark spots which, when numerous, may fuse together into large diseased areas, as shown in the illustration, and these becoming dry and brittle may easily be whipped into a ragged condition. In the attacks on sweet cherry leaves, the shot-hole effect is rarely met with. The typical appearance is well illustrated by the accompanying photograph. In the case of cherries, but not of prunes as far as we have observed, the fungus may attack the stems of the fruits, causing the fruit to shrivel. Cases have been observed where a considerable part of a good crop of cherries was rendered practically worthless by the disease. When the disease is abundant, the presence of numerous leaf infections will cause the foliage to drop off. In the sweet cherry especially the affected leaves often first turn a bright yellow, which has led many to call the trouble the "yellow-leaf" disease of cherry. I once observed a thrifty mature cherry orchard practically defoliated by the disease before mid July and have often seen sections of prune orchards nearly bare of leaves by mid August, as is well depicted in the photograph.

After watching the variations in severity of this disease in Western Oregon for a number of years, one is led to the conclusion that serious epidemics may be expected only in years when rainy spells are continued well into June or July, the early establishment of dry weather being unfavorable to the disease. Trees that stand in an orchard in locations where they suffer from excessive evaporation, as on hill tops, or where they feel the effects of deficient soil moisture, appear, according to reports from many growers, to be more seriously affected than trees on lower levels and better supplied with moisture. For some reason even in the worst seasons many orchards escape severe attack while others not far distant stand with branches almost bare in the August sun. The disease is somewhat spasmodic and Western Oregon growers have no reason to expect a continuation of the freedom from this disease brought about by

Fig. 43. View of an Italian prune orchard, showing severe midsummer defoliation due to leaf-spot disease.

the exceptionally early and prolonged drouth conditions of the years between 1916 and 1920.

EXPERIMENTAL WORK ON CONTROL

The increasing severity of Cylindrosporium attacks in the prune orchards south of Salem and the consequent alarm of growers led to an experiment on control in an orchard in this section in 1916. The work was carried out in cooperation with the manager of the orchard, Mr. C. O. Constable, and under the direction of the writer by G. B. Posey, G. K. Van Gundia, and O. H. Elmer. The object was to determine in a preliminary way whether the disease could be prevented by keeping the foliage covered with a fungicide, what fungicide would be most successful, and what the proper dates of application might be.

Six applications were made: the first week in April, the first week in May, the first week in June, the last week in June, the third week in July, and the third week in August; and the plots were so arranged as to give an indication of the separate value of each application. The fungicides tested were bordeaux 4-4-50, lime-sulfur 1 to 45, and Atomic Sulfur 6 to 50. The degree of defoliation in the different plots in late summer was used as an indication of the relative efficiency of the applications.

The results showed clearly that the first and the last two applications in the series of six had no value for leaf-spot control. Trees receiving the three intervening sprays showed practically perfect control with the bordeaux, and fairly good control with Atomic Sulfur. The lime-sulfur applications given during the hot weather of the summer caused severe leaf burning and so much defoliation that it was impossible to check on their fungicidal efficiency. The use of a soap spreader with the bordeaux added very greatly to its covering power. The condition of the foliage sprayed through the season with bordeaux was noticeably more vigorous, a darker green, and longer lived than in the other plots. Unsprayed trees adjoining the sprayed plots showed severe defoliation due to the presence of the disease.

RECOMMENDATIONS

Although the results of the 1916 tests in this one orchard were convincing, yet the Experiment Station undertook the following season to carry on a more complete and elaborate series of tests designed to verify the previous results and to obtain further information regarding the disease. The complete absence of the leaf-spot trouble in 1917 brought these efforts to naught, however, and no further opportunity to carry on this work has occurred since. The following recommendations are necessarily, therefore, based only on the one set of tests as reported in this article.

(1) Wherever the leaf-spot trouble has previously appeared in an orchard, spray thoroughly both the upper and lower surfaces of the foliage with bordeaux 4-4-50. The addition of a spreader is useful. Make the first application about May 1 and repeat at intervals of three or four weeks until dry summer weather is permanently established. If rainy spells continue through the summer, late applications may be needed, but as a rule three sprays should suffice in the Willamette Valley.

(2) Get rid of the old leaves as completely as possible before the new growth begins to appear. Plowing before blooming time is good for the tree as well as being an aid in burying a large portion of the disease-carrying foliage.

Note: The sprays for leaf-spot will also be a great help in keeping down brown rot.

PHYSIOLOGICAL DISORDERS OF DEVELOPING FRUITS

By H. P. Barss

Every year the plant pathologists of the Oregon Experiment Station are confronted by many inquiries regarding the cause for and control of troubles which affect many kinds of fruit in the course of their development, but which upon careful study appear not to be caused by parasitic organisms like fungi or bacteria. A survey of the situation through the State discloses the fact that these disorders are widespread, that they cause very large damage at times, and that, although varying in severity from season to season, they are present in some form to a greater or less extent every year.

In general the growers appear to be unacquainted with the nature of diseases of this sort. Usually their presence arouses the fear that they are evidences of the invasion of some new pest or infection, the advance of which may be expected ultimately to threaten the entire crop or in time to destroy the value of the orchard. Observations extending over a good many years, however, show that these fears as to the communicable nature of the troubles are unfounded; that the severity of these outbreaks over the State is closely connected with seasonal climatic conditions, and that in individual orchards they are often related to the soil conditions and horticultural practices associated with the particular place.

Before discussing any of the different types of physiological fruit injury it might be well to consider some of the problems and conditions which the growing tree and developing fruit have to face during the growing season. Of all the requirements of plant life none is more important than water. The successful development of the tree and its fruit depends at all times upon the successful maintenance of the necessary balance between the outgo and intake of water. Water is constantly given off from the leaves in the form of vapor and the warmer and drier the air and the more rapid its motion the faster will the moisture be evaporated from the foliage. The rate at which water is given off is under the control of the plant to only a very limited extent.

Under all conditions it is upon the root system that the tree must depend for its supply of water to meet this unavoidable evaporation, and the root system must get it from the soil. It can readily be seen that anything which upsets the balance between the rate of absorption of water by the roots and the rate of water loss from the parts above ground will at once affect the growth and activities of the tree in an unfavorable manner. In general, an abundant supply of water means rapid growth whether of leafy shoots or of developing fruit. With a diminution of the water supply, growth must slow down, while in extreme drouth growth stops altogether, and the tree is forced to drop its fruit and foliage in order to cut down the amount of evaporation, and in this way restore somewhat the water balance within the tree.

As stated before, the rate of evaporation from the leaves is greatest when the temperature is high and the moisture in the atmosphere (relative humidity) is low. On the other hand, cool temperature and higher atmospheric humidity cut down the rate of evaporation. The amount of water loss from a tree in the orchard, therefore, is usually greatest in the dry, clear, hot weather of the summer time and in the middle of the day, while it is much smaller in the cool, moist weather of the spring and fall, and at night.

With these facts in mind it will not be difficult to understand that in the Pacific Northwest, with its almost complete freedom from summer rains and with its dry summer atmosphere, orchard troubles due to the excessive evaporation and insufficient water supply are of frequent occurrence. In fact, the astonishing thing is that our highly-developed

fruit varieties manage to get along so successfully under the critical variations and extremes presented by their environment.

When a tree either gradually or suddenly meets with conditions which upset its water balance or cause rapid variations in the rate of growth, it is natural to expect that any fruit developing on the tree will be affected. Within recent years a number of American investigators, including Chandler, Mix, Coit, and Hodgson, have shown that when the evaporation of moisture is in excess of the water supply the leaves will forcibly extract water from the fruits, particularly when they are unripe. This has been demonstrated for most of our common fruits. In California orange groves during hot, dry weather the rate of evaporation may be so great at midday that the roots even under conditions of abundant irrigation cannot keep up with the demand of the leaves for water. Then the fruit loses water to the foliage during the daytime and shrinks in size, only to come back again to full turgidity by night, when cool temperatures and increased humidity cut down the evaporation rate and bring about a restoration of the water balance in the tree. Perhaps the fruit of the orange is so constructed that it can stand a considerable amount of this sort of thing, but it is not surprising that some other kinds of fruit appear to exhibit injury sooner or later under similar conditions.

Not only must excessive evaporation or deficient soil moisture be looked upon as serious sources of danger to the developing fruit, but sudden and violent changes in the conditions surrounding the tree can only be expected at times to upset the delicate adjustments which govern the natural course of the growth processes taking place within the fruit. Sudden drouth has its tendency to stop growth and to induce shrinking of the fruit and concentration of the juices within its flesh, but the effects may be no worse than the sudden provision of an abundance of water after a dry period, resulting in sudden expansion of the fruit with the possible development of tensions and pressures which would perhaps cause the rupture of cells in the flesh or the breaking of some of the delicate veins which extend like a network through the pulp, bringing materials for further growth. Sudden cold and sudden heat must likewise make severe demand upon the powers of adjustment, which the tree and fruit possess.

Mention might also be made of the possible effects on the fruit of failure on the part of the foliage to perform its proper functions. The leaves being the food-manufacturing organs of the tree, the fruit must depend upon them for nourishment. Any influence affecting unfavorably the vital activities of the foliage must, then, in some manner, affect unfavorably the growth and development of the fruit. Among the influences which can only retard the natural work of the leaves may be mentioned not only insufficient water supply, but also excessive heat and sunshine and chemical deficiencies or other undesirable chemical relations in the soil. It is quite reasonable to suppose that such conditions add in one way or another to the tendency of the fruit to exhibit abnormalities.

In the light of all our knowledge about plant life and the intimate relations existing between soil and climatic conditions and the development of the fruit, it is only to be expected that in regions of great soil diversity subjected to variable or extreme climatic conditions disorders of the developing fruit due to environmental influences must be common, and this expectation is realized in the occurrence in Oregon, as elsewhere in the Northwest, of many types of injury on various kinds of fruits, which can only be explained as the direct or indirect results of harmful soil and climatic conditions.

A great deal of scientific study has been devoted to physiological troubles of this kind, but such investigations meet with difficulties not present in the study of bacterial or fungous pests and the acquiring of definite knowledge as to the exact causes is necessarily slow. Although

the conditions responsible for many of these troubles are still more or less the subject of conjecture, yet gratifying progress is being made and many valuable facts have already been learned. D. F. Fisher, plant pathologist for the United States Department of Agriculture, with headquarters at Wenatchee, has worked for a number of years on physiological fruit diseases in the Northwest, and it is to him that we owe much of the information we now have regarding their nature and causes.

Most of the troubles to be discussed here are attributable to an upsetting of the water balance or equilibrium of the tree. This is not always a result of an excessive depletion of moisture in the soil. It is always a consequence, however, of the inability of the roots to supply fully as much moisture as the foliage and fruit demand. It is not unusual to find instances where blossoms are withered and blighted in the spring, simply because the roots of the trees, standing in a water-logged soil, are not able to absorb sufficient water and pass it on to the tree because of the lack in that soil of the oxygen necessary for vigorous root activity. It is also not uncommon in the spring, even where soil conditions appear satisfactory, to see the fruit and foliage suffer from lack of water, because injudicious ploughing has cut off a considerable portion of the feeding roots. Oftentimes root-systems growing in shallow soil or soil having an impervious or impenetrable layer not far from the surface cannot make a growth adequate to meet the demands of the expanding top, even with a reasonable amount of moisture available in the surface layers. Root

Fig. 44. On left, cluster of grapes showing a shriveled or corrugated condition of many berries, due probably to effects of excessive evaporation from foliage in hot weather. Upper right hand apple shows "apple blister," caused by sudden cutting off of water from tree as fruit is commencing growth. Left hand apple shows "drouth spot," caused by severe water deficiency during late spring or early summer. Lower, Italian prune fruits showing "gum spot," due probably to upset water balance in the tree.

rots, rodent injury, borers, heart rots, etc., may also interfere with the ascent of sap sufficiently to deprive the top of the tree of its full requirement of water.

Even with healthy and vigorous root systems and deep, moist, well-aerated soil a tree or plant may sometimes show an upset water balance. This is particularly true when soil and climatic conditions have been favorable for an excessive vegetative growth in the early part of the season. In such instances, when dry, hot summer weather comes on, the amount of evaporation from the over-abundant foliage is so great that even the healthy root system cannot work fast enough to meet the demand, although if top growth had been more moderate no trouble would have been experienced. Thus it is not always the trees which show lack of vigor, but often those which are in reality of more than average vegetative vigor which may show distress from an excess of evaporation over absorption of water.

General observations show that there are great differences in the ability of different varieties of the same kind of fruit to withstand unfavorable surrounding conditions. It has been noted that the fruit of some varieties may shrink or wilt in times of drouth only to resume normal development again with a restoration of the water balance, while under the same conditions the fruit of other varieties may develop permanent internal injuries, which are never obliterated.

Of the physiological injuries to which the apple is commonly subject as the probable result of insufficient water-supply, the first that may be mentioned is what Fisher has called **"apple blister."** This is illustrated in Fig. 44. It comes on, according to Fisher, very early in the growth of the fruit, just as it is setting, and is characterized by the appearance of slightly raised, irregular, brown or reddish spots, which are hard and corky, but which affect only the outer surface. In Oregon this appears not to be common except in the driest fruit-growing sections.

A little later in the development of the apple there may appear what is known as **"drouth spot."** This is illustrated in Fig. 44. Spots that look water-soaked first appear on the fruit surface and drops of a sweet, yellowish ooze often exude from the injured areas, later hardening on the skin. Just beneath such spots in the flesh of the apple groups of brown and dead pulp cells are found in the region of the delicate network of veins lying close to the fruit skin. As the season progresses the affected fruit does not expand properly and these drouth spots remain sunken so that the fruit is often badly distorted. The worst case of this drouth spot that the writer has ever seen occurred in a Hood River orchard which the owner had deeply plowed rather late in the spring The severe root pruning suddenly cut off from the trees much of their water supply, and as a result the fruit was a total loss from the development of the drouth spot. Fisher reports that this condition is apparently always associated with a sudden interruption or reduction of the water supply. It is most common in our irrigated sections.

More common in Oregon than the foregoing are the troubles which may be classed under the designation of **"cork."** In cork the spots of dead, brown tissue appear more deeply sunken in the flesh of the fruit or about the core. There is often no external evidence of the trouble other than a slightly duller green color than normal and a somewhat rubbery feel. In other cases, however, a slight depression may be noticeable over the more superficial spots. This cork or "dry rot" condition has caused much loss in this State in the past, particularly in Hood River, but in that section better irrigation practices have resulted in overcoming the trouble to a very large extent. It is associated usually with inadequate water supply during the mid-growing season. In many ways it is so similar to the drouth spot as to lead to the suspicion that it is only the result of similar causes affecting the fruit later in the course of its development.

Among other physiological apple troubles whose contributing causes are not yet very clearly understood, may be mentioned **"punk"** and **"hollow apple,"** or, as McAlpine of Australia has called it, **"crinkle."** In the case of "punk," which was apparently more common than usual in Oregon in 1920, the flesh of the fruit is characteristically punky, being dry and mealy and streaked with brown or brownish throughout. The writer has seen this condition in peaches and quinces as well as apples. Crinkle or hollow-apple is a condition in which large continuous areas in the flesh of the fruit become dry and brown, the cells often collapsing so as to leave open spaces in the pulp. The surface of fruit so affected is often shrunken and crinkled. Both these troubles seem to be associated with drouth conditions, perhaps coupled with direct exposure to intense sunlight.

Fig. 45. Baldwin apple showing typical appearance of bitter pit.

"Bitter pit," or "Baldwin spot," of apples is another disorder which is both widespread and often the cause of serious losses in Oregon. It is characterized by the appearance of pits or depressions in the surface of the fruit, usually most abundant toward the calyx end. This trouble does not usually show up until the maturity of the fruit, often not appearing until after it has been picked. Each pit or depression has beneath it a patch of dead cells lying close to the skin. Baldwin, Grimes, Yellow Newtown, Ortley, and several other varieties are particularly subject to bitter pit. Water relations late in the growing season are probably involved in the development of this trouble. From the work of Brooks and Fisher it would appear that practices which tend to provide the orchard trees throughout the season with a steady and adequate but not excessive supply of soil moisture will tend to counteract the disease.

Pears are not infrequently affected by "cork" in much the same manner as apples, showing internal brown spots in the flesh and around the core, but the trouble is not as common or serious as in the case of apples. In the hotter and drier sections of Oregon pears, especially the Bartlett, may be affected by what, for want of a better term, we may call **"black end."** It is characterized as shown in Fig. 46 by a black discoloration of the skin, which makes its appearance close to the calyx end and may extend backward until in extreme cases nearly the entire surface of the fruit may be affected. Fruits showing this trouble are usually abnormal in shape, being rounded at the calyx end instead of depressed. The flesh is involved only to a very slight extent, but the affected skin and the layer of flesh immediately beneath become hard and dry and may crack, as shown in the illustration. The blackened region usually merges indefinitely into the healthy skin, but sometimes there is a definite margin and the blackened portion becomes slightly depressed. Every effort to discover a parasitic organism in the diseased tissues has failed, and all the circumstantial evidence points to the probability that excessive evaporation in hot weather or insufficient soil moisture are responsible for its development, since it appears usually on soils either unfavorable for root growth or unretentive of moisture or both.

Fig. 46. Black-end disease of pear, resulting probably from unbalanced water relations.

Prunes are likewise subject to disorders which are probably due to unbalanced water relations. The **"gum-spot" or "drouth spot"** trouble illustrated in Fig. 44 has been very common in Oregon during the past few seasons, at least. It comes on just about in mid-season and appears first as watery-looking spots on the fruit. These usually swell and burst open by a crescent-shaped slit, from which there is an exudation of transparent gum that hardens on the surface. In the flesh of such prunes small brown flecks always appear, beneath the gum-spot. These usually consist of a few dead pulp cells situated in the region of the outer network of veins. Such injury is often slight and the prunes mature with very little evidence of the trouble. More severe injury, however, may result in the death of larger areas of the pulp. The resulting collapse of the tissues and cessation of growth produces an irregular or corrugated surface. Such affected prunes usually color up prematurely and drop off.

In some years, as the prunes approach maturity, great losses to growers result from an internal breaking down of the flesh, with brown discoloration and disagreeable odor, which has sometimes been erroneously mistaken for brown rot. This **internal browning** usually starts immediately around the pit, but often extends outward until in some cases it reaches the skin and involves the whole flesh. The trouble is not of fungous or bacterial origin, but is presumably due to disturbed water balance in the tree and perhaps is similar in origin to "punk" in the apple.

Grapes are not exempt from drouth troubles. As shown in the accompanying illustration the berries may shrivel on the vine in mid-season. Growers sometimes consider this the result of exposure to direct, intense sunlight, but recorded instances show that some of the worst cases on European varieties in Oregon have appeared on vines which had exceedingly luxuriant foliage, so that the bunches were unusually well shaded. It is hard to avoid the suspicion that in such instances the shrivelling has been due to the removal of moisture out of the fruit to meet the excessive requirements of an overabundant foliage.

Specimens of a trouble in grapes of the Concord type were sent to the Experiment Station from several sections of Western Oregon in the fall of 1920. Externally the grapes looked all right, but internally there were dead brown dry spots in the pulp surrounding the seeds, reminding one strongly of "cork" in the apple. No fungous or bacterial parasite could be detected microscopically. The trouble should probably be classed with the others, therefore, as due to environmental influences.

Walnuts are subject in dry seasons to a trouble which seems not unlike the black-end of pear. The outer end of the hull turns dark and the shell within fails to form completely at the apex, so as to give a perforated effect. Walnut growers have undoubtedly been correct in attributing this to drouth conditions.

Potato tubers often show isolated brown spots through the flesh, as shown in Fig. 47, which are known not to be the result of parasitic attack. Every indication points to the conclusion that excessive transpiration is in some way involved in the development of this **internal browning** of the potato.

Other Oregon crops besides those mentioned are also affected by similar lack of adjustment between water needs and water supply. Berries, for example, frequently shrivel on the fruiting canes after they are well set. Then, too, the tomato crop is almost always reduced to a considerable extent by the development of the blossom-end rot described elsewhere in this report by McKay. Taking into consideration all the information available, it is evident that these physiological fruit troubles constitute a very serious problem for Oregon growers.

After considering the nature of these disorders and their probable contributing causes, little doubt must remain as to the direction in which

growers must work, if the losses due to them are to be reduced in the future. Sprays will naturally be of no avail. Only those practices will help which will tend to promote steady and healthy, but moderate growth of the tree, bush, or vine, and which will tend to keep constantly available an adequate but never excessive supply of soil moisture. The object in mind must be to maintain that balance between the emission of water vapor from the leaves and the absorption of soil moisture by the roots that is essential to perfect fruit development.

Many Western Oregon sections would probably find it a highly profitable form of insurance against these troubles to introduce moderate irrigation where none is now practiced, but irrigation is not a cure-all, for many soils even under irrigation would not be adapted to successful fruit production. Soils incapable of satisfactory drainage, like heavy clays, soils subjected to seepage, shallow soils, and soils not retentive of moisture, should naturally be avoided. Furthermore, careless or injudicious irrigation may easily increase rather than reduce these disorders. Wise summer pruning should be something of an aid in maintaining proper water balance. The use of cover crops in Hood River, in connection with improved irrigation methods, has helped materially to overcome former serious losses from physiological fruit troubles, and it is very likely that similar methods might be successfully adapted to other fruit sections. Each locality, however, and, in fact, each orchard, presents its own peculiar set of conditions, which must be closely studied before the most satisfactory solution of its problems can be worked out. But it is certain that until these problems are worked out in a practical way the losses from these physiological disorders of developing fruit will increase year by year as our orchards grow older and make constantly greater demands on the soil and its limited natural supply of moisture.

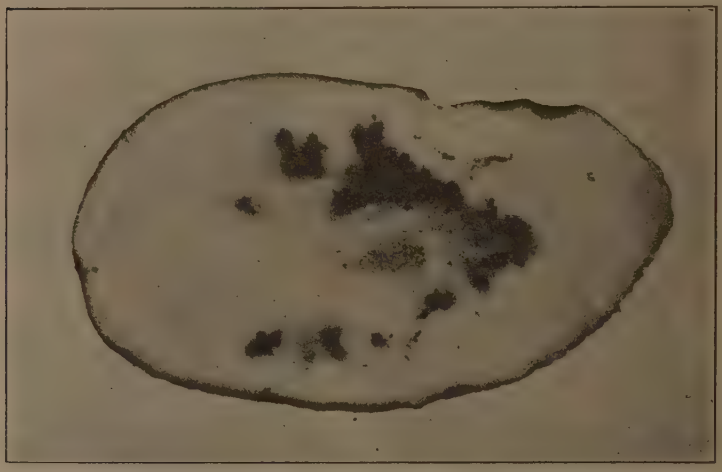


Fig. 47. Potato tuber showing internal brown spots, presumably due to the effects of soil and climatic conditions.

NOTES ON TESTS WITH FUNGICIDES

By H. P. Barss and W. A. Smart

PRELIMINARY TESTS WITH LATE SUMMER SPRAYS FOR APPLE-TREE ANTHRACNOSE

The destructiveness of the apple-tree anthracnose canker disease in Western Oregon and its continued prevalence even in orchards sprayed somewhat systematically after the picking season has emphasized the importance of getting a good spray covering on the bark if possible before the first fall rains that usher in the anthracnose infection period. Hitherto this has not been the general practice, although growers have sometimes used bordeaux in late August or early September for this purpose. The heavy deposit left by this spray on the fruit, however, was not only objectionable in itself, but on red varieties led to a blotchy appearance of the coloration. It seemed desirable, therefore, to test out other and less conspicuous fungicides to be used as a late summer spray. The experimental results proved somewhat disappointing, but it is felt desirable that the growers be informed of the results.

The first tests along this line were made at Corvallis in the late summer of 1919. Burgundy mixture, 2-3-100, was used. The spray was much less conspicuous on the fruit than bordeaux, but early in the fall rainy weather occurred and shortly afterward evidences of what appears to have been soluble copper injury showed at the lenticels on the fruit surface, with both red and yellow varieties. The same experience was met with by several orchardists who had given the later summer or early fall Burgundy spray. These experiences made it clear that ordinary Burgundy mixture (2-3-100) could not safely be used when rainy weather was likely to follow. As to the effectiveness of this material for anthracnose control no definite evidence was secured, since the freeze of December of that year killed most of the trees in the test orchard.

During the past summer it was decided to make further efforts to discover a satisfactory late-summer or early-fall anthracnose spray and tests were made with six different materials. These were bordeaux 4-4-50, bordeaux 2-2-50, Burgundy 2-3-100, neutral Burgundy 2-3.68-100, copper soap 1-2-50, and Magnesium-Bordeaux 2 to 25. Sulfur-containing sprays were avoided for fear of burning in hot weather. The bordeaux sprays were used both alone and with the addition of several spreaders: soap, glue, gum arabic, casein, and miscible oil.

For spreading power miscible oil, one gallon to 100 gallons of spray, proved the most successful. With its use the drops of the spray, as soon as they touched the fruit surface, flattened out and united in a thin, even coating. Where too much spray was applied it had a tendency to run down to the lower surface of the fruit and drop off or leave a slightly denser deposit at that point. Casein used at the rate of eight ounces to 100 gallons of spray, gave the next best results. With any of the materials used as spreaders there was an improvement over the bordeaux alone, and with the oil and casein there was no tendency for the spray to leave the usual conspicuous speckled or spotted deposit on the skin.

These sprays were applied on a Yellow Newtown orchard at Corvallis in connection with the last codling-moth spray on August 10. It will be remembered that rainy weather came on very early in the fall of 1920 and in unusual abundance. As a result, early in September an examination of the experimental orchard showed that in the plots sprayed with any of these copper-containing sprays a considerable percentage of the fruit showed more or less of a reddish speckling on the sunny side, due to a blush of color about some of the natural breathing pores or lenticels on the skin. The unsprayed check block did not at that time display this condition. Reports of damage from similar red spotting on

bordeaux-sprayed trees were shortly sent in by orchardists in various localities. The following long rainy period saw a good deal of this blemishing on yellow fruit, even in orchards that had not received any late summer spray. The unsprayed fruit in the experimental plots showed some of this spotting, though less than the sprayed fruit.

Close examination of affected fruits disclosed the fact that the tiny lenticels around which the reddening occurred were split open. This splitting of the lenticles has been noticed before and comes usually, if not always, after a rainy spell late in the development of the apple. The exact cause is not known, but perhaps it is due to the tensions resulting from the stretching of the fruit skin as the apple, after the dry summer, takes on a sudden new growth with the advent of abundant moisture. Whatever the precise cause, the fact remains that this cracking is in some way connected with the red spotting.

The prompt appearance of this condition on sprayed fruit leads to the suspicion that as soon as splitting occurred the soluble copper of the spray on the skin was washed into the crack and poisoned the exposed cells, with consequent chemical changes which produced the red coloration about the spot.

In unsprayed fruit the splitting of the lenticels probably affords opportunity for molds, yeast, and bacteria of various kinds to settle in the cracks and start growth in a small way, which finally induces a similar reddish tinge in the surrounding skin. In other years the workers in the laboratory of Plant Pathology have found a great variety of microscopic organisms at such points on affected fruits. Sometimes they cause the formation of a small sunken black or brown spot around the lenticel, but do not make further increase in size like a true rot. Blemishes of this type on the fruit are always most troublesome in wet autumns.

Fig. 48. Red spotting on Yellow Newtown apple, showing up after early fall rains and presumably induced by copper poisoning at split lenticels. Similar effects often occur on unsprayed fruit in rainy autumns, but more tardily and due possibly to growth of organisms in the lenticels.

It is a source of regret that the tests described have not pointed the way to an early fall or late summer anthracnose spray that is safe in wet seasons. The Experiment Station expects to continue its search for a satisfactory solution of the problem. Meanwhile, it seems probable that the owner of an orchard badly attacked by anthracnose will find it to his advantage to put on this early anthracnose spray and thus secure additional protection against both the canker and fruit rot infections, even though in very wet autumns he may run the risk of some red spotting of the fruit.

SUGAR AS A STABILIZER FOR BORDEAUX MIXTURE

It is a well-known fact that ordinary bordeaux mixture, if left standing a number of hours, will settle out of the liquid and change from a fluffy blue precipitate to a purple crystalline deposit. This change makes the bordeaux of little value for spraying.

In connection with certain tests with fungicides conducted in 1917 by H. P. Barss and A. E. Murneek, the addition of sugar in definite proportions was found to stabilize bordeaux mixture and prevent its breaking down. The work was repeated in 1919 by W. A. Smart, and more delicate determinations were made on the precise amount of sugar needed to give the best results.

As a consequence of these tests it has been determined that deterioration of bordeaux can be successfully prevented by the addition to the spray mixture of one-eighth of an ounce of ordinary granulated sugar for every pound of copper sulfate (bluestone) used. Bordeaux thus treated can be held an indefinite length of time and used the same as freshly-made bordeaux. This method will save the spray for future use when rain or a break-down prevents the grower from finishing out his tank.

For a 200-gallon tank of 6-6-50 bordeaux, which will require twenty-four pounds of bluestone, dissolve three ounces (seven heaping teaspoonfuls) of sugar in a little water and add slowly to the tank of spray, agitating until thoroughly mixed. Too much sugar must not be used, as it causes the copper to dissolve. For small amounts of spray, dissolve one well-rounded, but not heaping, teaspoonful of sugar in one quart of water, then use at the rate of one-half pint of this solution for every pound of bluestone going into the amount of bordeaux required.

IRON SULFIDE, AN EFFECTIVE AID TO THOROUGHNESS IN SPRAYING

Thoroughness of application is one of the great secrets of success in orchard spraying. Recently, on the advice of the Experiment Station, many growers have adopted a simple method in connection with lime-sulfur sprays whereby it is made very easy to tell as the work is being done just how perfectly the foliage and fruit are covered by the spray operator. The value of the method is self-evident and its results are greatly appreciated by careful orchardists who have tried it. The directions are as follows:

Iron Sulfide Indicator. Take half as many pounds of iron sulfate (copperas) as you use gallons of concentrated lime-sulfur in the spray tank. Dissolve the crystals in water and add this solution to the tank of dilute spray. As a result the tank full of spray will turn black in color, due to the formation of black iron sulfide, which, some days after application, turns into red iron rust. The spray loses practically none of its fungicidal efficiency as a result, nor is there any other undesirable effect, but the spray operator can now tell instantly how well he is covering the trees, because of the black color of the material. The tops of the trees or a projecting branch cannot now be missed without detection and the result is an appreciably larger percentage of perfect fruit in the harvest

at insignificant cost and little trouble. (Note: After application, the black color changes slowly to rusty reddish.)

DRY LIME-SULFUR VS. ORDINARY LIQUID LIME-SULFUR

In recent years manufacturers have developed a method for transforming lime-sulfur into a powdered form known as dry lime-sulfur. This material is far more convenient to handle than the ordinary form and requires only to be mixed with water in the proper proportions to make a spray solution practically identical with the ordinary lime-sulfur spray in effective chemical constituents. It proves to have effectiveness for the control of the same pests and diseases as the liquid lime-sulfur, but when used in quantities sufficient to give the diluted spray the same constituent strength as the usual dilutions of the liquid material it is far more expensive than the latter.

Dry lime-sulfur of several makes has been analyzed by R. H. Robinson of the Oregon Experiment Station as well as by the chemists of other stations. These analyses and those printed on the container labels by the manufacturers show that it takes not less than four pounds of the dry material to equal one gallon of the ordinary commercial liquid lime-sulfur in sulfur or polysulfide content, on which the effectiveness of the spray depends. In other words, not less than 200 pounds of dry lime-sulfur are required to equal one 50-gallon barrel of the concentrated liquid.

The manufacturers recommend dilutions of dry lime-sulfur which are considerably weaker than the dilutions of liquid lime-sulfur ordinarily used for the same purpose, usually about half normal strength. They claim that at these weak strengths their material will give successful control. These claims cannot be disputed until careful and fair comparative tests have shown that they are incorrect. The Experiment Station has carried on several tests, which, although not extensive, have given results which ought to be taken into consideration by the grower who is interested in securing the best possible control of fruit diseases.

In 1917 and 1918 a well-known brand of dry lime-sulfur was tested at Corvallis for control of peach leaf-curl, along with other materials. This material was used at the rate then recommended by the manufacturers for the dormant spray of twelve pounds to fifty gallons of water. Ordinary commercial liquid lime-sulfur was used at the same time at the dormant strength of 1 to 8. The final results showed that while some control was secured by the dry lime-sulfur it was on the average distinctly inferior to the control secured with the ordinary liquid, as might well have been expected when it is considered that the strength of the dry lime-sulfur was only about half that of the liquid material.

Comparative tests on apple-scab control were then attempted at Corvallis in 1919 and 1920, but the conditions were very unsatisfactory and the results so variable and conflicting that no sound conclusions could be drawn from them.

A much more satisfactory test, however, was conducted in 1920 at Monroe in the vigorous and well cared-for Oaco orchard. The season was extremely favorable for scab development and the variety selected, Yellow Newtown, is one of the most highly susceptible varieties. Three plots were selected for the test and these were all sprayed under the direction of Mr. C. J. Currin, foreman of the orchard, by the regular orchard force with a high-power outfit and spray guns. Five scab sprays were given, two before and three after blossoming. All three plots were sprayed with dry lime-sulfur at the rate of one pound to sixteen gallons for the "early cluster" (delayed-dormant) application, one pound to twenty gallons for the second, third, and fourth applications, and one pound to twenty-five gallons for the last. The second plot was sprayed with ordinary lime-sulfur at the rate of 1 to 100 for all five sprays. This gives a dilution equivalent approximately to dry lime-sulfur used at the rate of one

pound to twenty-five gallons. The third plot was sprayed with ordinary lime-sulfur at the rate of 1 to 30 for the first application, 1 to 40 for the second, and 1 to 50 for the last three.

Mr. W. A. Smart of the Experiment Station made a careful record of the crop from representative trees in each plot at picking time. The results showed a consistent difference in effectiveness in the three plots. The plot sprayed throughout the season with weak lime-sulfur (1 to 100) gave the poorest control, an average of 28% of the fruit being scabby. The dry lime-sulfur plot was better, with an average of 19% scabby, but this was distinctly inferior to the results from the regular lime-sulfur schedule, which gave only 7½% scabby fruit.

In Hood River in 1917 a test was carried on with dry lime-sulfur (8 pounds to 100) in comparison with the regular lime-sulfur spray for apple-scab control. The conditions of the test were not exactly ideal, according to Leroy Childs, who carried on the work, and perhaps too much weight ought not to be placed upon the results, but they showed that when unsprayed check trees had over 15% scabby fruit, the dry lime-sulfur plot showed a little over 3% scabby, as compared with 2% for the plot sprayed with ordinary lime-sulfur. Since that time there has been so little scab in the test orchards at Hood River that successful comparisons have been impossible.

While the comparative tests conducted in Oregon thus far have been too few in number to justify the formation of a positive opinion as to relative merits, yet the results of those which have been carried on appear to indicate that dry lime-sulfur cannot be expected to yield results equal to those secured by the ordinary dilutions of liquid lime-sulfur unless it is used at more nearly equivalent strengths than the manufacturers have recommended up to the present time. Growers are advised to make comparative tests for themselves and the Experiment Station would be glad to learn the results.

CONTROL OF MOSS AND LICHENS IN THE ORCHARD

By W. A. Smart

The long, mild, moist fall and winter seasons usually experienced in the sections of Oregon that lie west of the Cascade Mountains and particularly the climatic conditions existing along the coast, are extremely favorable for the growth of mosses and lichens, so much so, in fact, that even the orchard trees become covered with an abundant development of these forms of vegetable life unless some special method is employed to get rid of them. Just how deleterious their presence may be to the tree is difficult to determine with precision, but the number of inquiries annually received by the Experiment Station asking how to get rid of them is an indication that their presence is not wanted by self-respecting orchardists.

It is well known that ordinary sprays such as those used for common fungous diseases in the orchard will keep down "moss," but it is frequently unnecessary to give regular annual sprayings with certain varieties of fruit or with nut trees to insure reasonably successful crops, and the question arises as to what are the best methods and materials to use in such orchards to keep the trees free from these undesirable incrustations.

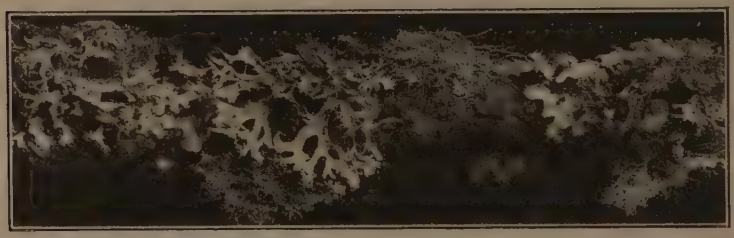


Fig. 49. Apple branch covered with lichens. Preventable by spraying.

PRELIMINARY INVESTIGATIONAL WORK

Work was conducted along this line by the Oregon Experiment Station during the 1919-20 season, which included spraying tests and also observations in a number of commercial orchards. At Corvallis an old, neglected, "moss"-covered orchard of apples, pears, prunes, and cherries was sprayed on December 5, 1919, using a power-driven outfit maintaining 250 to 275 pounds pressure. The luxuriant growth of lichens was saturated as thoroughly as possible, a spray gun being employed for the application. The following materials were used:

Bordeaux mixture, 6-6-50.
Lime-sulfur, 1 to 8.
Lime-sulfur, 1 to 8 + lye 1 pound to 6 gals.
Lime-sulfur 1 to 8 + miscible oil 1-100 + glue ½ pound to 100.
Sherwin-Williams dry lime-sulfur, 1 pound to 4 gals.

The results from these sprays as noted at the end of the 1920 growing season were practically the same for all the different varieties of trees. The trees sprayed with bordeaux mixture finally came out the cleanest of all, while those sprayed with the winter-strength lime-sulfur came next. The spray in which lime-sulfur was combined with common soda lye prove to be the most immediate and rapid in its action, since it caused very prompt disintegration of the growth on the branches. In the long run, however, its effects were not as complete as those of either

bordeaux or lime-sulfur. The other two materials tested were inferior in effectiveness to those previously mentioned.

In the winter of 1917 the filbert orchard of Mr. George Dorris at Springfield was sprayed to get rid of the lichens, bordeaux 6-6-50 being used. Observations made more than two years later, in the spring of 1920, showed the trees to be still remarkably free from lichen growth, although they had not been sprayed in the meantime. Bordeaux, then, appears to have a particularly enduring effect in keeping trees clean. A survey of the conditions in a number of commercial fruit orchards demonstrated in a clear way that the usual sprays regularly employed for protection against various fungous diseases are effective in keeping down the lichens so that no special sprays for "moss" are required in plantings systematically sprayed for other troubles. The prevalence in many orchards of lichen growth in the tops of the trees but not in the lower portions is a demonstration of the fact that the grower is not thoroughly covering the topmost fruit and foliage with his spray applications and that he should use a higher-powered spray outfit or use a tower to reach the tops. Otherwise diseases and insect pests as well as the lichens cannot be controlled with complete success.

RECOMMENDATIONS

For apples, pears, and peaches which are regularly sprayed for apple and pear scab, apple tree anthracnose, peach blight or peach leaf-curl, as advised in Experiment Station publications, no special "moss" spray will be required. Wherever strong lime-sulfur for the control of scale is given on any variety of fruit the lichens will also be prevented.

For fruit or nut trees which are not sprayed for fungous diseases or scale the growth of lichens and mosses may be kept down by a late fall or winter spray of bordeaux mixture 6-6-50. Lime-sulfur 1-8 will also accomplish the clean-up in nearly as satisfactory a manner even though the effects may not be as lasting. A driving spray under high pressure should be employed and the growth on the branches thoroughly saturated.

WESTERN YELLOW TOMATO BLIGHT

By M. B. McKay

For several years the tomato growers of Oregon have been seriously handicapped by the disease of the plants commonly called Western Yellow Blight. This disease has occurred in a number of western states, including at least Oregon, Washington, and Idaho, and up to the present time has not yielded readily to the control measures that have been used. It is the desire now to redirect attention to this disease so that it may be accurately recognized, and to mention the control measures which may be of possible value in helping to alleviate the losses now occasioned by it.

DESCRIPTION OF THE DISEASE

The disease is seldom ever seen before the plants produce their first flowers, and in many instances it does not appear until the fruits are half-grown. From then on to maturity it becomes of increasingly common occurrence until by the end of a bad blight year more than half of the plants are seriously afflicted. The first indication of the disease is a slight rolling of the leaves and purpling of the leaf veins. In time this rolling may continue until the leaves and leaflets are distinctly rolled upward and inward, followed generally by drooping, but not wilting of the foliage (Fig. 50). At the same time the plant loses its normal green color, at a distance often appearing greyish with a tinge of light purple. This may soon give way to a yellowing of the whole plant. With the development of the disease there is a marked cessation of growth, and the fruits, even though small and immature, appear to ripen. Plants blighted late may produce a part of a crop. Fruits that are considerably stunted in size are, however, not used commercially, though they are agreeable to the taste. If the root system of a blighted plant is examined, it will be found that many of the smaller feeding roots, especially at their tips, are dead and that some of the larger branches are discolored and decaying. The outer tissues of these may be easily slipped off between the thumb and finger, leaving behind the inner small strand of the harder, more woody tissue. The buff or light brown color and the softness of these diseased roots are in considerable contrast to the clear white and firm condition of healthy roots.

CAUSE OF THE DISEASE

The preliminary laboratory work done and the field observations made in the State indicate that the disease is caused chiefly by a species of Fusarium, a fungous mold in the soil, which attacks the roots of the plants, causing them to decay as noted above. This fungus apparently works in the outer layers of the root tissues, causing them to soften and rot away. A few cases have been found in which Rhizoctonia, another soil fungous mold, was attacking the root system in a somewhat different way, causing the development of brownish canker-like areas on the larger roots and the death of a number of the smaller ones. The work of either of these parasites on the roots interferes to such an extent with their function of supplying water and food materials to the plant that it is not able to maintain itself in a healthy condition. Thus the rolling of the leaves and the purpling and final yellowing of the whole plant above ground follows, and this condition appears to result from the diminished food and water supply. Any environmental condition, such as soil and air temperatures and wind velocity, which would tend to increase the loss of water from the plant and therefore to increase its demand for more water from the soil, would tend to aggravate the seriousness of the disease. These external factors are, no doubt, contributing circumstances, but are evidently not the primary causes of the trouble. The mechanical

breaking of the stem tissues from being whipped about by the wind also stimulates the appearance in the plants of symptoms indicative of Western Yellow Blight. Thus plants exposed to extremes of temperature or of wind, blight worse than those given better protection. The blight develops, however, even in places exceptionally well protected from the wind.

The condition of the plants as generally found in Oregon is in agreement with the findings of the earlier, more complete studies[6] which have been conducted on the disease, of which Fusarium was found to be the

[6]Humphrey, H. B., Studies on the Relations of Certain Species of Fusarium to the Tomato Blight of the Pacific Northwest, Wash. Agr. Exp. Sta. Bul. 115, 22 p., 5 pl., 1914.

Fig. 50. Tomato plant severely attacked by Western yellow blight. The leaflets are distinctly rolled upward and inward, followed by slight drooping, but not wilting of the foliage. The plant has lost its normal green color, which has given way to a yellowing of the whole plant, and appears somewhat greyish, with a tinge of light purple at a distance. A plant as severely affected as this will produce no fruit of any commercial value. The symptoms as shown by the foliage are only an indirect effect of a parasite on the roots, which has attacked and killed a large number of them.

cause, in the state of Washington. More recent work conducted mainly in a different region of Washington[7] indicates that in some localities Rhizoctonia is the chief cause of such trouble. The evidence to date goes to show that this is the same species of Rhizoctonia which causes damping off in young tomato plants and which also attacks potatoes so commonly. Thus there appear to be two organisms working on the roots of tomato plants and giving results in the tops which cannot be readily distinguished the one from the other. Additional work will be necessary to determine which of the two organisms is the chief offender against tomatoes in the state of Oregon. As stated above, however, Fusarium appears to be the more common and important one of the two.

DISTRIBUTION AND IMPORTANCE OF THE DISEASE

The exact distribution of the disease in Oregon is not known because the whole region has not been surveyed. Specimens have been received, however, from many widely-scattered localities, and it is suspected of occurring, to some extent at least, wherever tomatoes are grown in the State. It is known to occur most severely in the Columbia river basin east from Hood River, a region where tomatoes are of the most value commercially. It is the chief limiting factor in the growth of this crop at The Dalles, where the earliest and best tomatoes in the State are grown. The annual loss there from this disease varies from a slight amount in occasional years to one-fourth of the crop in the average year, or to more than one-half of the crop in the exceptionally bad year. The acreage devoted to tomatoes, moreover, is now small compared to what it would be if the Western Yellow Blight did not exist.

Outside of Oregon the disease is known to have occurred only in Washington and Idaho. The reason it is thus confined to the Pacific Northwest is not known, but may lie in some peculiar soil and climatic factors.

CONTROL OF THE DISEASE

The disease cannot be definitely and absolutely controlled by any practical measures yet devised. This is largely due to the fact that the organisms causing the disease remain alive for a considerable length of time in the soil, are able to attack a number of other plants than tomatoes, and seem to occur to some extent in soils never previously cropped to tomatoes. The most that can be done under the circumstances is to use the sanitary and precautionary measures which will help to hold the trouble in check and reduce the damage as much as possible. Some of the more important of these measures may be listed as follows: Avoiding undue injury in transplating the young tomato plants; protecting the plants in the field from extremes of wind and sunshine; maintaining cultural conditions favorable to rapid and continuous growth of the plants; avoiding the use of diseased soil in seed beds and field; disinfection of soil in seed beds and cold frames; rotation of the land with non-susceptible crops, and the use of varieties resistant to the disease.

Any injury which the young plants suffer in transplanting is a distinct shock and sets them back proportionately, while not hindering the attack of the disease. Thus any means that aids in the early, rapid, unchecked growth of the plants permits the attainment of larger plants before the disease develops. One practice that some growers use to considerable advantage is the setting of the young plants in paper bands for further development in the cold frames. This enables the plants to be set in the field with much less injury, as the paper is not removed when the plants are permanently set. Another practice that some growers use and that merits wider use is the planting in the greenhouse of a few—three or four—seeds in a tin can with the top removed. When these

[7]Heald, F. D., Tomato Blight, Report Wash. State Hort. Assoc. 12, pp. 35-42, 1916. Also Better Fruit 10; Mar., pp. 37-40; Apr., pp. 36-37, 1916.

are well up, all but the one best plant are removed and this one is allowed to grow undisturbed until time to set the plants, when the entire contents of the can are slipped out and set in the field with very little injury. Another method which promised considerable value in the experimental trials in Washington is the early planting of a few seeds under a small glass-covered box, 12 inches by 12 inches by 12 inches, in the field. The hills are properly spaced in the field and a forkful or so of well-composted manure is placed under each hill to furnish the early heat desired. When well started, all but the one most promising plant is removed and this one is allowed to grow to maturity without ever being removed. When the plant is about six inches high and requires no further forcing or when conditions warrant it, the glass covering is slipped out of its grooves and the box is left in place to protect the young plant from the wind, etc. This box also aids in holding the branches and fruits from coming in contact with the soil during later development. This method must be tried more extensively in Oregon before it can be unreservedly recommended, though, as mentioned above, in the trials conducted in Washington it appeared to have great merit.

Some growers have considerable success in holding the disease in check by the use of natural or artificial windbreaks, such as hedges, brush fences, etc. These should be provided wherever it can be conveniently done, for they are quite beneficial; they are not sufficient, however, absolutely to prohibit the appearance of the disease. The individual plants when first set in the field should be protected by placing on their windward side a V-shaped shield made by nailing together two boards about 9 inches by 15 inches in size and strengthened by a cleat nailed across the top connecting the outer ends of the V. Some growers let this shield stand about the plants throughout the season to aid in holding the fruits from coming in contact with the soil.

A field culture should be practiced which will maintain for the growing plants an abundant supply of moisture and plant food. This will have the effect of overcoming some of the loss of the absorbing roots through the attacks of disease. Barnyard manure may be used liberally to stimulate the growth of the plants. Good cultivation for the aeration of the soil is also an important factor.

Due to the fact that the organisms causing the disease remain alive in the soil for a considerable length of time, no soil which has recently contained diseased plants should be used in the seed beds or cold frames for starting young plants or for growing plants in the field. The planting of tomatoes in contaminated soil greatly increases the risk of securing a diseased crop.

Occasionally it is desired to use in the seed beds soil that is known or suspected to be infected with the disease. Such soil ought to be disinfected before being used. This may be done by the use of steam or boiling water. According to a recent Government Bulletin,[8] soil may be conveniently disinfected by drenching it thoroughly and repeating as soon as the soil takes up the water, using actively boiling water at the rate of seven gallons per cubic foot of soil. Before treatment, the soil should be thoroughly spaded up and preferably quite dry so that it will readily take up the water. After being treated it should be covered over with canvas, sacks, or some similar material to hold the heat for a few hours, after which it should be left exposed for five to seven days to dry out sufficiently for planting. For the disinfection of soil in flats, pots, or other small containers, these may be submerged in boiling water for five minutes, then removed and covered over for two hours to retain the heat.

Crop rotation is in general one of the most valuable means for plant-disease control. There are cases, however, where this method is ineffec-

[8] Byars, L. P., and Gilbert, W. W., Soil Disinfection With Hot Water to Control the Root-Knot Nematode and Parasitic Soil Fungi, U. S. Dept. Agr. Bul. 818, 14 p., 5 pl., 1920.

tive, due to the fact that the organism responsible for the disease stays alive more or less indefinitely in the soil, may occur on many different host plants, or may even be present in soils never before planted with any cultivated crops. In Western Yellow Tomato Blight, we appear to have one of those diseases for which crop rotation is not a reliable control measure. This is shown by the fact that tomatoes grown on land never previously planted to this crop have frequently been known to blight badly. The planting of tomatoes year after year on the same land does not always mean that the disease will increase in extent or severity. It remains true, however, that rotation with non-susceptible crops does give greater chance to avoid disease than where tomatoes are grown continuously on the same land, and this should be made use of at every opportunity consistent with other conditions.

To the development of blight-resistant varieties or strains we must look with greatest hope for our future deliverance from this disease. This is strictly a future hope, however, and is not at present an accomplished fact. But the fact that so many other diseases are being successfully overcome by the use of resistant strains, justifies the hope that this disease of tomatoes also will be finally overcome by this means. To date no real progress has been made along this line. In 1919 four varieties of tomatoes, Arlington, Columbia, Marvel, and Norton, secured from the United States Department of Agriculture as resistant to tomato wilt in the East, were tried for resistance to blight at The Dalles, but without success, as they were all susceptible to this disease. Previous to this, other strains had been tried without notable results. Work along this line will be continued. Every grower should be on the lookout for individual field plants which seem to have resistance to blight and should make selections of these for trial. Select from a badly-infested part of the field only the plants that are free from the disease, and plant the seed of each selection in a separate row or plot in soil known to harbor the disease. Determine the relative merits of the selections from the average disease resistance and from the yield and quality of fruit of their progeny. Do not mix selections nor save seed from any but the one that transmits the most desirable qualities to its progeny. When this is found, multiply it and use it as seed for the field crop.

The county agricultural agents and the Oregon Agricultural Experiment Station stand ready to aid whenever possible in this work of selecting and testing blight-resistant strains of tomatoes and should be called on for advice or assistance whenever it is desirable. The attention of these agencies should be called to any variety or selection of tomatoes which seems to possess resistance to blight.

MOSAIC DISEASE OF TOMATOES

By M. B. McKay

During the past summer for the first time the attention of the laboratory of Plant Pathology was called to an occurrence of the mosaic disease on tomatoes in Oregon. This is a disease of not uncommon occurrence on tomatoes in other parts of the United States and of other countries, and has been known for many years. It has no doubt occurred in former years in Oregon, but has perhaps not been of serious enough consequences to attract unusual attention to it on the part of many growers. After its occurrence in the State was known, a careful survey revealed the fact that it was present and causing damage on tomatoes in widely-separated localities and on plants grown from seed secured from entirely different sources. It appears, therefore, to be of sufficient importance to warrant calling the attention of growers to it and giving briefly the salient facts known concerning its nature and control.

DISEASE CHARACTERS

The disease in its typical form is characterized by the occurrence of irregular mottled areas on the leaves due to the loss on the part of some portions of the leaves of their normal green color, which fades to a yellowish or light greenish tinge. This gives on the leaves alternate irregular areas of normal green and lighter green, which suggests the name mosaic (Fig. 51.) This loss of color varies from a slight, almost imperceptible amount up to an extreme condition in which the yellow areas in the leaves are greater in extent than the areas of normal green. In almost all cases the normal green is retained most persistently along the veins and midribs. In addition to losing color the leaves become also somewhat crinkled and do not remain flat like the normal leaves. Plants affected by mosaic are not as resistant to unfavorable conditions as healthy plants. Consequently if the temperature gets quite high or other factors are too far off the normal, numerous small brown dead spots develop on the leaves as a result of the killing of the weakened tissues.

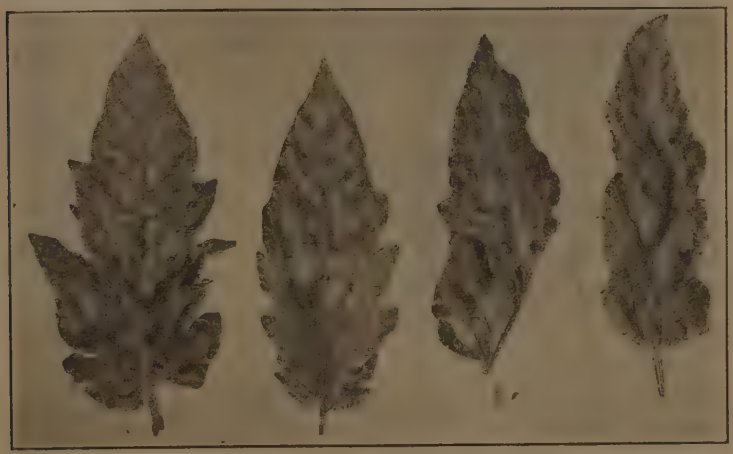


Fig. 51. Mosaic disease on tomato leaves. The leaflets show the usual form of the disease in which irregular areas of the leaves lose the normal green color, become yellowish or light greenish and are somewhat crinkled.

This brown spotting is a secondary combined result of the mosaic disease and the abnormal environmental conditions, though if examined only superficially it might easily be mistaken for a separate and characteristic bacterial or fungous leaf spot. Another defect of the mosaic disease is to cause a gradual reduction in the size of the leaf blade on the new leaves formed. In extreme cases this results in the growth of narrow, ribbon-like leaves and occasionally the midrib itself is the only leaf tissue that develops (Fig. 52). It should be borne in mind that only the new growth which is produced after the plant becomes infected shows any of the symptoms of the mosaic disease. The color or form of the older leaves already present on the plant does not subsequently change as a direct result of the disease. If the effect of the mosaic is severe enough, as occasionally happens, the new growth is so held back that the plant is ultimately considerably stunted as compared to healthy plants.

Occasionally on mosaic-diseased tomato plants will be found fruits which are irregularly spotted and cracked (Plate XIV). This spotting and cracking may become noticeable after the fruits are half grown and usually become more pronounced as the fruits grow older. The spots are brownish blotches in the surface tissues of the fruit and apparently only the epidermis and a few nearby cells are affected, as the other underlying tissues appear to remain unchanged. The spots vary in size. Up to about a quarter of an inch in diameter they are free from cracks. When larger areas are affected the epidermis becomes broken. At times practically the entire surface of the fruit is affected, being stained a brownish color and covered irregularly with a network of surface cracks with only occasionally a small patch of normal green unaffected tissues remaining. The first-formed fruits are affected much less severely than

Fig. 52. Leaves from a plant extremely affected by the disease, the leaf blades being greatly reduced in size and in some cases entirely wanting. This is a more unusual though not rare type of the trouble.

PLATE XIV

Irregularly spotted and cracked fruits from a tomato plant badly affected by mosaic. The upper, first-formed fruits are affected much less severely than the lower, later-formed ones on the same cluster. This is likely due to the increasingly deleterious effect of the mosaic disease on the plant as it grew older. This type of trouble is not frequently encountered and has not been experimentally demonstrated to be due to mosaic, yet its peculiar nature and the fact that it was found only on plants badly affected by mosaic strongly suggest the causative relation of this disease.

the later-formed ones on the same cluster. This is likely due to the increasingly deleterious effect of the mosaic disease on the plant as it grows older. The badly-affected fruits are of course unsalable, and even the lightly-spotted ones are quite conspicuous from the bright chocolate-brown color to which the spots turn as the fruit ripens. Aside from the shallow surface spots and cracks the fruits are sound in every way and do not rot unless invaded by secondary organisms. This type of trouble is not frequently encountered and has not been experimentally demonstrated to be due to mosaic, yet its peculiar nature and the fact that it was found only on plants badly affected by mosaic strongly suggest the causative relation of this disease.

CAUSE OF THE DISEASE STILL UNKNOWN

The cause of the mosaic disease of tomatoes still remains unknown in spite of all the careful work which has been done on it and on this type of disease in other plants. A large number of important cultivated plants are now known to be affected by mosaic diseases, among which are the following: potato, tobacco, tomato, cucumber, bean, and sugar cane. In no case, however, has the exact nature of their exciting cause been discovered. The two most plausible and most widely-accepted theories are, (1) that mosaic is caused by an organism which is so small as to be below the limit of visibility with the microscope and to pass through the filters ordinarily used for filtering out bacterial and fungous organisms, and (2) that it is caused by the over-production within the plant of certain enzymes which so disturb the normal metabolism of the plant as to result in the development of the mosaic symptoms.

Even though the exact cause of tomato mosaic is not known, there are some important facts concerning its nature which have been demonstrated. Of these the following may be mentioned here: The disease is infectious and contagious. It is readily transmitted to a healthy plant by injecting into it juice pressed out of a diseased plant. About a week or ten days after this is done the new growth coming out will show mosaic symptoms. The same result may be accomplished by crushing between the fingers a leaf of a diseased plant and then at once gently crushing a leaf of a healthy plant with the same fingers, so that the tissues are slightly broken and some of the juice from the diseased leaf will have an opportunity to enter. Or this may be done also by pruning a diseased plant and then immediately pruning a healthy plant with the same knife. Thus it will readily be seen that if the disease gets started among the young plants it may easily be spread from plant to plant during transplanting, or later it may be scattered in the pruning and other operations.

CHIEFLY A GREENHOUSE TROUBLE

In the eastern part of the United States and in parts of Canada where tomato mosaic has been known to be present for several years it has occurred chiefly as a greenhouse trouble. It occasionally causes considerable loss, however, in tomatoes out of doors. A report from Canada[9] records as much as 55% of the plants affected by mosaic in one field. This was an exceptional occurrence, as the average number found diseased in a total of about 18,000 plants examined in two years was 3.4%. Figures taken on the total yield of fruits from fifty-nine diseased and fifty-nine healthy plants showed a crop increase from the healthy over mosaic plants of 36.8% in number of fruits and 40.5% in weight of fruits. These figures indicate that individual growers may suffer considerable loss from the mosaic disease. Figures are not available on exact reductions in yield that mosaic has caused in individual cases on tomatoes in Oregon. A crop of greenhouse tomatoes was seen in June, 1920, however,

[9]McCubbin, W. A. 1918. The diseases of tomatoes. Canada Dept. Agric., Division of Botany, Bul. 35, 16 p. 8 figs.

in which 75% of the plants were noticeably attacked by mosaic. The yield on most of these plants was appreciably reduced and quite a number were producing not more than one-third of a crop. In the cases of disease observed out of doors there were a number of plants producing a very small crop, indeed, though the yield of other plants was not noticeably reduced. The seriousness of the disease is apparently determined to a considerable extent by environmental factors, being apparently greatest under high temperature and other unfavorable conditions.

SOME POSSIBLE CONTROL MEASURES

In order to avoid getting mosaic started in a new planting of tomatoes three chief sources or possible sources from which the disease may be contracted should be borne in mind. These are the soil in the old beds, old tomato plants growing in the same house or near the bed where the young plants are being started, and other plants than tomatoes themselves which may carry the disease. Probably the chief source for holding over the disease from one crop to the next is the old soil in the seed beds and cold frames. It is well, therefore, to change entirely this soil or to disinfect it before using it again. For this purpose steam, hot water, or formaldehyde may be used. The disease is not so apt to persist in the soil in the field as it is in the beds.

Occasionally in greenhouse work it happens that old tomato plants are still growing in the same house or close to where it is desired to start a new lot of young plants. This should be strictly avoided, as it furnishes an unusual opportunity for the young plants to become infected early from the older ones. The young plants should be started in a place well isolated from all others. In this connection it would be well to emphasize the danger from some other plants than tomatoes. The evidence collected to date by workers on mosaic diseases indicates that tomato mosaic is caused by the same virus or agency that causes tobacco and petunia mosaic[10] and probably potato mosaic.[11] At least mosaic may be induced in tomatoes by transferring diseased juices or grafting diseased shoots from these plants to tomatoes. There may also be other plants, even including uncultivated ones, subject to the same virus. It is well, therefore, to plan the operations with these things in mind in order not to run undue risk.

Another possible source from which the disease may be contracted that should perhaps be mentioned is insects, especially plant lice. It has been shown that curly top of sugar beet,[12] a disease comparable in some respects to tomato mosaic, is probably over-wintered through the agency of insects. Apparently the disease is carried by leaf hoppers from beets to wild plants in the fall and then from these or other susceptible wild plants back again to beets in the spring. Also potato mosaic[13] is carried from one plant to another by the common green peach aphis, or spinach aphis. Tomato mosaic is likewise communicable from plant to plant by means of plant lice and where crops are grown in the same or nearby greenhouses in close succession insects might prove to be a factor of importance in carrying over the disease. Where one wishes to avoid this possibility, thorough fumigation of the house before replanting would be advisable. It is fortunate that the disease is apparently not carried in the seed from one year to the next; at least, if this does occur it is an extreme rarity. In this respect tomato mosaic is quite different from bean mosaic, which is carried extensively in the seed.

[10] Allard, H. A. 1916. The mosaic disease of tomatoes and petunias. Phytopathology 6:328-335. 2 figs.

[11] Quanjer, H. M. 1920. The mosaic disease of the solanaceae, its relation to the phloem-necrosis and its effect upon potato culture. Phytopathology 10:35-47. 11 figs.

[12] Carsner, Eubanks. 1919. Susceptibility of various plants to curly-top of sugar beet. Phytopathology 9:413-421. 7 figs.

[13] Schultz, E. S., and Folsom, Donald. 1920. Transmission of the mosaic disease of Irish potatoes. Jour. Agr. Res. 19:315-338. 8 pls.

After tomato mosaic is once started in a planting there is not much that can be done to overcome it. The only thing that can be done is to avoid, as much as possible, spreading it during pruning, pollinating, cultivating, and like operations, and to provide conditions especially favorable to the plants so that the effects of the disease will be offset as largely as possible by the resulting increased vigor. In order to avoid undue spreading of the disease, it is sometimes desirable, after having handled diseased plants, to get rid of the virus on the hands before passing on to work with healthy plants. For all practical purposes this may be accomplished by washing them thoroughly with warm water and soap. If aphids or other insects apt to carry the disease from plant to plant become abundant they should be controlled by fumigation or by spraying.

The disease is of such a nature that it is doubtful whether it can be controlled practically by roguing out the diseased plants. This is due to the fact that by the time the disease is noticeable enough in one plant to be rogued it may already have been transferred to some of the neighboring plants, even though they do not as yet show any of the symptoms. Diseased plants, moreover, may still produce a fair crop of fruit, if conditions are favorable, so that the added loss of pulling out such plants would be unnecessary. If only a few diseased plants are discovered, however, it might be well to rogue them out promptly. High temperatures, dry soil, poor ventilation, or other unfavorable conditions tend to add to the deleterious effect of the disease. Consequently, the most favorable growing conditions possible should be provided to enable the plants to withstand the weakening from the disease and still yield a fair return. In a report on some work done in Ohio[14] it was stated that the use of nitrate of soda at the rate of 200 pounds per acre applied as a liquid about mosaic-diseased plants resulted in an increased vigor of the plants treated. These methods, of course, never eliminate the disease nor restore the plants to normal; they help only to lessen the losses.

[14]Humbert, J. G. 1918. Tomato diseases in Ohio. Ohio Agr. Exp. Sta. Bul. 321:159-196. 12 figs.

BLOSSOM-END ROT OF TOMATOES

By M. B. McKay

From time to time during the past several years specimens of tomato rots have been received from correspondents, with inquiries concerning the nature of the troubles and requests for control measures. The great majority of these specimens received have been of the rot commonly known as "blossom-end rot" or occasionally as "point rot." Observations by staff members also have shown that this rot is of rather common occurrence in the State, particularly during or following a period of dry weather. Consequently, it seems advisable to give briefly at this time the important facts known concerning its nature and control.

This rot, as its name implies, affects tomato fruits at the blossom end. It often appears about the time the first fruits are half grown and from then on to or somewhat past the middle of the season becomes of increasingly common occurrence, though the exact time of its onset and duration depends on external conditions. The first indication of the disease is a slightly sunken, water-soaked area at or near the base of the style, either lead-colored or brownish, which soon turns to dark brown or black (Fig. 53). Often the rotted area is quite shallow and does not commonly extend more than a quarter or half an inch in depth, although on the surface it may enlarge quite rapidly until a considerable portion of the fruit is involved. Finally the affected tissue becomes black, hard, and leathery and the tomato much flattened. It is not uncommon, however, for an affected fruit to ripen with less than a third of its area affected by the end rot. Partly rotten fruits, of course, have no value commercially, though they are quite palatable and are suitable for table use after the affected portions are removed.

The results of all the work on the cause of the disease that has been done by various investigators[15] [16] strongly indicate that it is not due pri-

[15] Stuckey, H. P., and Temple, J. C., Blossom-end Rot of Tomatoes, Georgia Exp. Sta. Bul. 96, pp. 69-91, Fig. 7, 1911.

[16] Brooks, Charles, Blossom-end Rot of Tomatoes, Phytopathology 4:345-374, 5 Figs., 3 Pls., 1914.

Fig. 53. Blossom-end rot of tomato fruits showing different stages of decay. Photo by H. P. Barss.

marily to bacteria or fungi, but mainly to unbalanced water relations in the growing plant. It may be induced by underwatering, in which case the plant is not able to secure enough water from the soil to meet all the needs of the growing tissues. The trouble seems to make its appearance when the water lost through evaporation from the leaves is greater than the amount the roots can readily take up so that some of the tissues suffer from an insufficient supply and moisture may actually be drawn out of the fruit by the needy foliage. The tissues of the blossom end of the fruit, being seemingly more sensitive to injury, collapse and die, turning brown and thus giving rise to the blossom-end rot condition.

The rather customary season of prolonged dry weather in July and August in Western Oregon resulting in a high evaporation rate accompanied by a rapid or undue reduction of the soil moisture frequently leads to the development of a considerable amount of blossom-end rot, while later, with a more liberal supply of moisture or a better balance established between the plant and its water supply, the tendency to develop the rot may disappear.

The trouble may also be brought on by conditions which, like heavy manuring or overwatering early in the season, promote such an extremely rapid vegetative growth that when the hot, dry weather of summer comes on the root systems are unable adequately to meet the demand for moisture caused by the naturally increased evaporation from plants of such large size. The result is the development of blossom-end rot even though the soil moisture supply at the time might not appear to be unduly depleted. Given a less rapid and better balanced growth of the plants in the earlier part of the season, the same moisture supply would probably bring to maturity a fair crop of fruit without any end rot.

Brooks[16] has also suggested that the liberal use of manures or other organic matter in the soil and heavy watering may lead to the development of harmful humic and ammonium compounds at the expense of soil nitrates and induce a condition favorable to the production of end rot in the fruits even through the supply of water in the soil is very liberal. Where end rot has a tendency to occur, therefore, manures should be used more sparingly and overwatering should be avoided.

Blossom-end rot, being often connected with a deficient water supply, can frequently be controlled by supplying a more adequate amount of moisture to the soil during the most critical periods of the season. Every effort made to keep a proper balance between the growth of the plants and the available moisture supply will help to prevent the disease. Where irrigation water is available and judiciously applied a minimum of trouble should be experienced. Where water is not available attention should be given to careful cultivation for the maintenance of good tilth, which will help to conserve the soil moisture supply, avoiding at the same time too free use of stable manure.

Spraying is of no value in the control of this disease, and since it is not infectious it cannot by controlled by picking and destroying the affected fruit nor reduced by crop rotation. None of the common commercial table tomatoes grown in the State are known to be resistant to the rot, although some of the small varieties of tomatoes, especially those used for preserving, are highly resistant to it.[17] The only practical control measures available, therefore, lie, as stated above, in the properly-balanced use of soil moisture, fertilizers, and cultural methods, so as to avoid the development of possible harmful compounds in the soil and insure conditions such that the growth produced in the plants in the early part of the season can be maintained through to maturity without the danger of injury from excessive evaporation or from an insufficient water supply in the soil.

[17] Stuckey, H. P., Transmission of Resistance and Susceptibility to Blossom-End Rot in Tomatoes, Georgia Exp. Sta. Bul. 121, pp. 83-91, 3 Figs., 1916.

ONION SMUT CONTROL

By H. P. Barss

According to the reports of the Bureau of Crop Estimates for the last three seasons there are from 750 to 800 acres devoted annually to onion production in Oregon, yielding crops valued at somewhere between three and four hundred thousand dollars to the farmer. It is, therefore, of no small concern to the State that so serious a disease as the onion smut has crept into our onion sections and already caused not only severe crop losses, but even the abandonment of some of the most profitable acreage. The investigations on methods of control here described were undertaken in 1918 after the attention of the Experiment Station had been called by F. R. Brown, then county agent in Marion county, to the devastating progress of the smut disease in the onion-set producing section in the northern part of that county, where the growing of sets centering about the town of Hubbard constituted an unusually successful enterprise, as may be judged from the fact that in 1916 over a million pounds were shipped from that one town alone.

As far as can be learned it was not until about ten years ago that onion smut was first noticed in the State, when it appeared on some of the onion farms in the northern Willamette Valley. Since that time it has continued to spread, particularly in the Tualatin and Pudding River sections, and to produce increasingly severe damage, particularly in the rich beaver-dam muck land. How the disease became first introduced is not known, but the most probable explanation is that it might have been introduced from other sections of the United States on big onions planted out in Oregon for seed production. The disease is quite widespread in onion-growing districts in the East and the smut spores could easily be carried on the surface of onion bulbs shipped out of these sections. It is possible also that the disease may sometimes be transported on the seed. When once introduced into a district it is apparently impossible to eradicate it from the soil and next to impossible to prevent its spread from farm to farm. Since a considerable amount of experimental work on the control of onion smut had already been done in the eastern United States and a so-called "formaldehyde drip" method worked out, the Oregon investigation of 1918 was designed to determine how successful this method would be under the conditions existing in this State and particularly for onion-set production.

CAUSE AND SYMPTOMS

The cause of onion smut is a fungus known scientifically as *Urocystis cepulae*. Infections arise from the microscopic spores that get into the soil from a diseased crop or in other ways. The onion plants become infected only as seedlings in the very early stages following germination. On penetrating the young seedlings, the tiny threads of the fungus grow through the tissues of the developing plant. After the seedling has appeared above the ground the disease makes itself evident through its stunting or dwarfing effect on the plants and by the production of dark-colored swellings or blisters on the leaves and bulb scales. These blisters after a time break open and let out the contained masses of minute black smut spores, which fall to the ground or drift like dust in the air, with the result that the disease is spread wherever they are carried, whether by the wind, on the feet of persons walking through the field, on agricultural implements used in the field, by irrigation water, or in other ways. Once the spores get into a piece of ground the smut fungus is able to live in the soil for a long time. In fact, it has been shown in the East that the disease may remain alive for at least twelve years in the absence of an onion crop. Hence, usual crop rotation methods cannot be expected completely to eliminate this disease.

When the infection is severe the plants that are attacked frequently die before they have reached more than two or three inches in height. A considerable percentage of smutted plants, however, survive, and in our 1918 spring tests it was shown that from 5% to 30% of the originally infected seedlings in each plot had recovered from the infection by the end of July. In such recoveries it was probably only the first leaf or two which were invaded, so that, when they eventually withered and dropped off, the onion plant matured normally and free from evidence of smut. The great majority of infected plants, however, do not recover, but remain dwarfed and distorted, a total loss to the grower and an agency for the perpetuation and increase of the disease in the field.

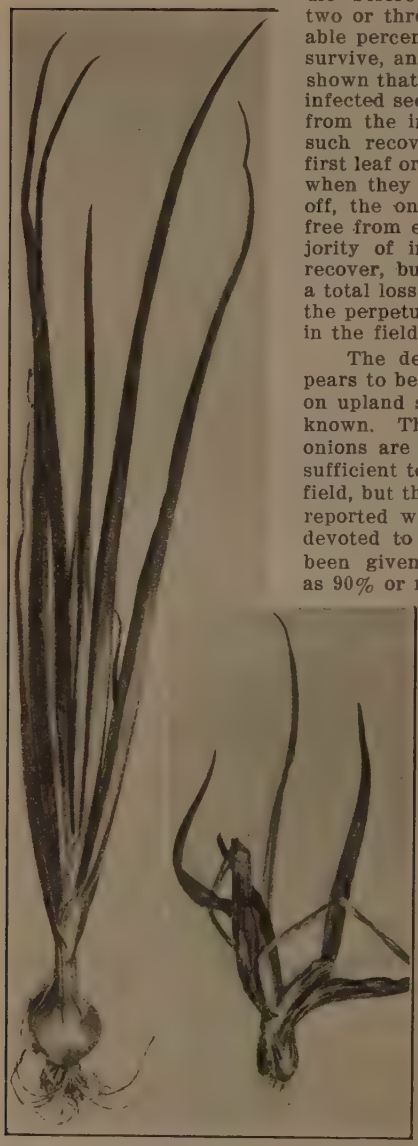


Fig. 54. Healthy onion plant compared with plant of same age affected by the smut.

The destructiveness of the disease appears to be much greater in muck land than on upland soils. The reason for this is not known. The damage in fields where large onions are grown is often considerable and sufficient to lead to the abandonment of the field, but the largest losses which have been reported were on beaver-dam soil formerly devoted to onion-set production, which has been given up because of losses as high as 90% or more of the crop.

EXPERIMENTAL WORK IN OREGON

The Oregon studies on control methods were conducted on a patch of beaver-dam muck land near Hubbard, which had been abandoned for onions on account of previous smut losses. Thanks are due to Geo. Leffler, the owner, for his cooperation in contributing not only the land, but much of his time as well, also to M. B. Kester, whose interest in the work and personal assistance made the experiments possible. The first series of tests was made on May 6, 1918. The seeder used was loaned by E. F. Miller. It is of local manufacture, constructed to seed five rows close together in a strip, a common practice of

onion-set growers in that section. An empty five-gallon kerosene oil can had been attached on top of the hopper with an outlet leading to five copper tubes, each of which conveyed the solution to one of the furrows, where it fell on the dropped seed and also soaked the surrounding soil before the trench was covered. Four plots were given treatments with various concentrations of formaldehyde, while a fifth was not treated with a solution, but planted with seed which had previously been mixed with dusting sulfur. Thirty days later the seedlings were examined, but the high percentage of infection (88% to 99%) in all plots appeared at that time to indicate that the methods used were of little or no value.

Shortly after this the writer seized the opportunity afforded by an eastern trip to talk with men who were conducting investigations on onion-smut control in Wisconsin, Pennsylvania, Ohio, New York, and also to visit the extensive investigations then being carried on at Williamson, N. Y. A comparison of the methods being tested in the East with the first Oregon tests disclosed at once the fact that the rate of discharge of the formaldehyde solution which had been used in the Hubbard experiments was entirely inadequate for successful control.

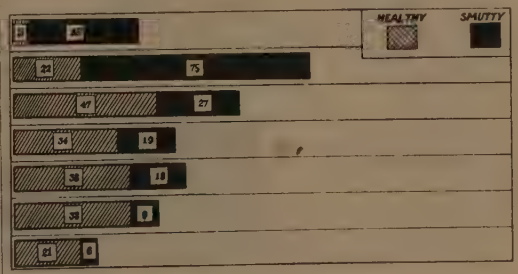
Another and more extensive set of plantings was made, therefore, on July 27 on ground adjacent to the first plots. It was necessary to use the same tank and outlet tubes as before, but the latter were opened to maximum capacity. An effort was made to study more in detail, as far as the apparatus permitted, the effect both of varying concentrations of the formaldehyde solution and of varying rates of flow. No further test was made at that time of sulfur dust, as the use of formaldehyde appeared more promising. Some of the interesting results of these second tests are presented in Tables XIV and XV.

From Table XIV it is evident that beginning with the weakest strength used, even though put on in small quantity, there was an immediate improvement over the untreated check rows in the total stand of plants and an increase in the proportion of healthy plants, although the percentage of smut still ran very high. The poor stand in the untreated plots was undoubtedly due to the death of many seedlings from smut in the six weeks intervening between planting (July 26) and the time records were made (September 5). It is noticeable, furthermore, from the chart

TABLE XIV. EFFECTS OF INCREASING STRENGTHS OF FORMALDEHYDE ON STAND AND SMUT CONTROL.

(Rate of application 1 gal. to 1,100 ft. in each seed row.)

Strength of solution.	Average stand in each 5 feet of seed row.	Per cent healthy	Proportion of healthy and diseased plants. (Six weeks after seeding.)
Check—untreated	41	12	5 35
1 oz. to 1 gal.	97	23	22 75
2 oz. to 1 gal.	74	65	47 27
3 oz. to 1 gal.	53	64	34 19
4 oz. to 1 gal.	57	69	38 18
5 oz. to 1 gal.	47	80	38 9
6 oz. to 1 gal.	27	78	21 6



that as the concentration of formaldehyde increases there is a rather regular decrease in stand, indicating that strengths greater than one ounce to one gallon are increasingly injurious to proper germination. At the same time the proportion of healthy plants among all that come up grows increasingly greater with increasing strengths of solution. The more perfect smut control at higher concentrations, however, is offset by the greater mortality due to chemical injury.

In Table XV it becomes evident that, when using the standard strength, an increase in the rate of application resulted in a rapid increase in the total stand of plants, which can only be explained as the effect of better smut control due to the use of larger quantities of solution. The best results in these tests, as indicated by the average number of healthy plants growing in a distance of five feet, was secured by using one ounce of formaldehyde to one gallon of water at the maximum rate of discharge which the outfit permitted, viz., one gallon to 275 feet of seed row.

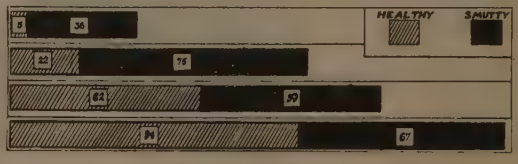
From these experiments it is apparent that we could not expect the answer to the problem of better smut control to lie in the direction of increasing the strength of the formaldehyde solution beyond one ounce to one gallon. On the other hand, it is quite probable that improved smut control and improved stand as well could be expected from the use of a still larger quantity of this standard solution than could be applied in the Hubbard test.

Since 1918 the Oregon Station has been unable to continue the onion-smut work. Meanwhile records of successful experiments on onion-smut control have been published by several investigators in other parts of the country. These have resulted in the establishment of a standard drip method entirely in accord with the results secured in the Hubbard tests. The strength recommended is one ounce to one gallon, applied at the rate of 200 gallons per acre or one gallon for every 185 feet of drill row, in seeding for large onions. The extremely satisfactory results secured by this method in the East indicate that it should solve the smut problem in a satisfactory way for the producers of large onions in Oregon.

The onion-set grower, however, has a problem involving greater difficulties. With the standard method he would have to apply nearly 1000 gallons of solution per acre, since in using the ordinary five-row drill, for example, it would be necessary to apply five times as much liquid as the single-row seeder would use in going the same distance. This means that a two- or three-gallon tank on a five-row drill would have to be filled up every 75 to 100 feet. A larger tank could not well be used, as it would weight down the seeder too much. It is evident that special methods and machinery ought to be devised for the onion-set grower.

TABLE XV. EFFECTS ON STAND AND SMUT CONTROL OF INCREASING THE RATE OF APPLICATION OF FORMALDEHYDE SOLUTION. (Uniform strength, 1 oz. to 1 gal.)

Rate of application.	Average stand in each 5 feet of seed row.	Per cent healthy	Proportion of healthy and diseased plants. (Six weeks after seeding.)
Check untreated..	41	% 12	
1 gal. to 1,100 ft.....	97	23	
1 gal. to 550 ft.	121	51	
1 gal. to 275 ft.	161	59	



The best solution of the whole onion-smut problem, however, and the one ultimately to be hoped for, lies in the discovery and development of types of onions resistant or immune to the disease.

RECOMMENDATIONS

The following is the standard method now in use in the United States:

(1) Take an empty five-gallon can or a tank of two- or three-gallon capacity and mount it, preferably lengthwise, between the onion seeder handles. An outlet pipe with at least $\frac{5}{16}$-inch bore should lead from the tank and end close to the furrow, so as to discharge the solution onto the seed just after it has reached the ground and before it is covered. This should be connected with the bottom of the tank by a $\frac{3}{8}$-inch lever-handle faucet with a $\frac{5}{16}$-inch opening through the body and key. An extension rod leading to the seeder handle should be attached to the key, as shown in the illustration, to permit easy and accurate adjustment of outflow. Such an outfit can easily be made by a good plumber or tinsmith.

(2) Before seeding, test the rate of flow and learn where to set the stop cock so as to deliver one gallon in about 185 feet when the operator is walking at a normal seeding pace.

(3) In making the solution, use full strength formaldehyde (about 37 percent) at the rate of one ounce to the gallon of water (one pint to sixteen gallons). It is handy to make up a supply in advance in a barrel and dip out to fill the seeder tank. Do not let the solution splash into the seed hopper when filling and adjust the discharge tube so as to avoid wetting the drill shoe and other parts of the seeder coming in contact with the ground.

(4) Remember that retarded germination, slow growth and deep planting give added opportunity for smut infections. Hence, the ground should be in the best possible condition for seeding, the weather favorable for rapid growth and the depth of planting not too great. In seeding, also, best results will be obtained when the drill is pushed at a steady, even pace to insure uniform application of the solution.

(5) Avoid spreading or increasing the disease. Do not return smutty screenings and culls to the field. Guard against accidental transfer of smut-contaminated soil, implements, etc., to uninfested ground. The same solution used in seeding may be employed to disinfect seeder, tools, boots, etc., used in a smutty field.

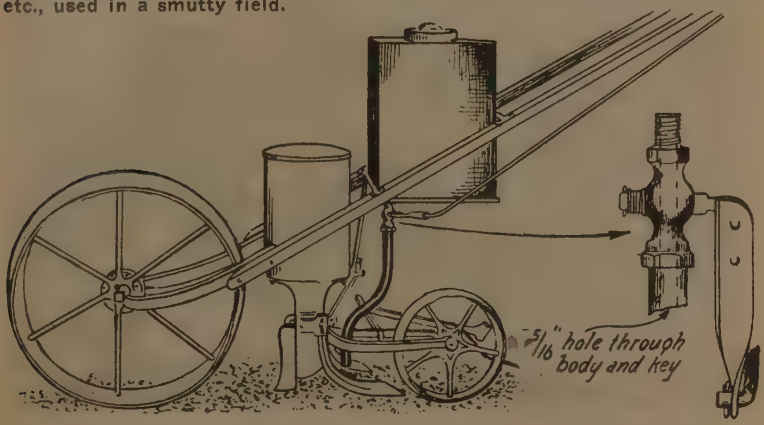


Fig. 55. A single-row onion seeder, showing formaldehyde drip tank, lever-handle faucet and discharge tube. From Circ. 114, U. of Wis. Col. Agr. Ext. Serv.

BEAN BLIGHT AND BEAN MOSAIC

By H. P. Barss

In the season of 1917 the attention of the Experiment Station was called to two diseases of beans, bean blight and bean mosaic, which had not previously been recorded as occurring in the State, although there is reason to believe that they had probably been in Oregon for some time. The seriousness of these troubles in the fields where they were first observed led to some further investigation of the situation, although, inasmuch as there has not been opportunity for any extended survey, the prevalence and distribution of the troubles are still only partly known. Both are well and unfavorably known in other parts of the United States. No thoroughly successful control measures have been discovered, so that their presence must be regarded with apprehension.

BEAN BLIGHT

This disease is caused by bacteria, presumably by the species known as *Bacterium phaseoli*, judging by the appearance of the organism in pure culture. It was discovered for the first time in many fields in and about Corvallis in 1917, where as high as a sixth of the plants were found affected in a single field. Diseased specimens were sent in also from two other localities in the Willamette Valley. Lady Washington, Mexican Tree beans, and a string bean variety were included in the diseased specimens that were examined. The sources of the seed were investigated as far as possible, but this led to no information as to the probable original source of the disease.

According to Eastern investigators, bean blight is often introduced by the planting of infected seed, but often spreads rapidly over a field through transfer from plant to plant by various agencies, including insects, spattering rains, and man, and his implements. In the diseased fields about Corvallis, however, there was very little evidence of transmission

Fig. 56. Plant on the left attacked by systemic vascular infection of bean blight. Plant on the right a healthy plant of the same age and variety.

from plant to plant. In numerous instances entirely healthy plants stood uninfected in the same hill with plants showing signs of the trouble. No spreading out from centers of infection could be anywhere observed, but the disease was usually scattered hit or miss through the fields. All the evidence, microscopic and otherwise, indicates that the disease had its origin internally in the seed from which the affected plants grew.

The first noticeable symptoms of the disease were usually the withering of certain leaves on the plant and a general stunting effect. Often, though not always, there appeared a dark-colored diseased or cankered area on the lower part of the stem centering at the point where the cotyledons had been attached and extending up and down the stem sometimes for a considerable distance as illustrated in Fig. 57. Not infrequently the girdled stems would break over at this point, as shown in Fig. 57. A great many plants, however, succumbed to the disease without showing these stem lesions. One after another the leaves would shrivel on the stems until all were dead, as illustrated in Fig. 56, where a healthy plant is shown standing beside one that had been killed. The foliage frequently showed conspicuous diseased areas. A typical example is seen in Fig. 58. The pods were only rarely found exhibiting external evidences of the trouble, but in such instances as did occur spots were present showing a water-soaked appearance, and often from them exuded glistening drops of a fluid containing myriads of bacteria.

Internal microscopic examination of the affected plants revealed the fact that in all cases bacteria were present in the water-conducting tubes in the stems, not only toward the base, but usually throughout the entire plant, followed out into the branches and into the leaf stalks and veins, often out into parts of the plant which as yet gave no external sign of their presence. In several instances the writer traced the presence of the bacteria in the water-tubes from the main stem out one of the fruiting branches, out through the stalk of an apparently healthy pod, out through the vessels of the pod and through the seed stalk into the well-grown seed itself, where yellow masses of the organisms surrounded the cotyledons and exuded onto the outside of the seed coats, there being with it all absolutely no outward sign to indicate that the disease was present in the branch or within the pod.

We have in this disease, then, what may be called a typical example of systemic vascular infection, originating from seed infection, penetrating

Fig. 57. Stem lesions caused by the bacterial blight. The breaking over of the stem at these diseased places is common.

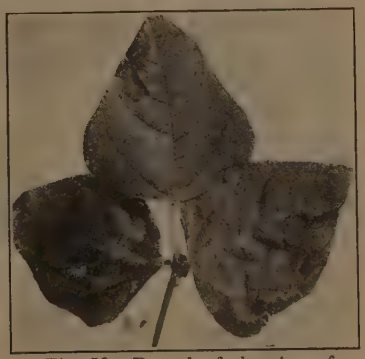


Fig. 58. Bean leaf showing effect of blight infection.

into the first-formed water ducts apparently from the cotyledons and spreading upward and outward into the leaves and growing stems and even into the seeds forming within the pods. Some of the infected plants died off almost before the first true leaves attained full growth. Others reached large size and developed mature pods before they died.

From the facts presented one cannot fail to see the difficulty of devising any successful direct means of control. In the East, growers have been advised to resort to pod selection because it had hitherto been supposed that the blight bacteria, attacking the foliage and pods from without, would always make their presence evident by producing typical spots on the affected pods. With internal infection as met with here, however, few of the pods give any evidence of the presence of the germs within. Pulling out the diseased plants might be employed to eliminate a good deal of the diseased seed from a plot, but many plants would not show evidences of the presence of the disease until late, and might escape detection, although the seed would carry the disease. Pod and seed selection or the roguing out of affected plants could be expected to yield only partly successful results.

Since 1917 very few cases of blight have come to the attention of the Station pathologists and it is hard to believe that this disease is really widespread or seriously troublesome in the State. Yet it is desirable that growers keep watch for its presence and notify the Experiment Station whenever it is found. The only really successful method of getting around this disease and one that is being practiced more extensively year by year in eastern sections, where the disease is so extremely destructive, is that of planting only seed grown in regions where the disease is not present. With disease-free seed we get disease-free plants and there is little opportunity for the blight to get into a field from outside, especially under such dry summer climatic conditions as we have in this State. It is by all means the best plan for Oregon bean growers to get their seed only from fields which inspection shows to be free from this and other diseases.

Fig. 59. Effect of mosaic disease on bean leaves. The leaf on the right is from a healthy plant for comparison.

BEAN MOSAIC

In the same year that the blight was first noticed, the writer came unexpectedly upon a patch of beans in Washington county which showed over 50 percent of the plants affected by the idease known as mosaic. Since that time the disease has been found in all parts of the State visited and in such abundance as to indicate that it has been in Oregon for a long time. The trouble is also now known to be present in most bean-growing sections of the United States. It is probable that very few bean fields in Oregon are without at least a trace of the disease and most show a large percentage of affected plants.

The disease is not difficult to recognize, once the typical symptoms are known. The characteristic effect on the leaves is that shown in Fig. 59. The leaves are distorted and pocketed or puckered. The leaf color is not a uniform green over the whole blade, but consists of irregular patches of a lighter green or even yellow interspersed amid the normal coloration. This gives the typical mottled or "mosaic" effect. The affected plants are also frequently slightly dwarfed and more bushy than normal plants. They fail to set pods entirely in extreme cases and always the yield is less than that of healthy plants. The symptoms are much more pronounced in dry weather and on soils lacking sufficient moisture, but even in the most severe cases the disease does not kill the plants. With an abundant water supply the symptoms may be almost entirely suppressed and pods may be set in considerable abundance. Plants that were severely affected throughout the summer have often been observed to make a vigorous renewal of apparently normal growth with the arrival of wet weather in the fall.

The mosaic disease is believed to be due to the presence of some organism so minute that it cannot be detected by the highest powers of the microscope. It is highly infectious, however, and may be carried from diseased to healthy plants by the agency of insects such as aphids. It is transmitted in the seed. A seed from an infected plant will produce an infected plant, although the disease-bearing seed cannot be distinguished from healthy seed. None of the bean varieties grown in Oregon are known to be immune from the disease. A bean of Mexican origin introduced into the Willamette Valley by C. E. Stewart and called by the Mexicans the Berrendo on account of its mottled appearance, has never shown any symptoms of the disease even when artificially inoculated, but after inoculation it may transmit the disease to other varieties, which will then show the usual symptoms.

Scientific investigators in Eastern states are now working diligently in the hope that commercially desirable types of white beans may be discovered which will show resistance to the disease, but progress in this direction is apparently very slow. Nevertheless it is along this line that the ultimate solution of the bean mosaic problem must be worked out. Meanwhile the best method of preventing the disease would be by the introduction of seed stocks of our common varieties from sources known to be free from the disease. The disease, however, is now so general that it is somewhat doubtful whether absolutely disease-free plantings exist anywhere. Nevertheless, the grower is wise who gets his seed from fields which show as little of the disease as it is possible to detect. At any rate it is certainly not prudent to plant seed from unknown sources. The safest plan is for the grower to get the best seed he can, establish his own isolated seed plot, culling out any suspicious plants as soon as discovered and using from then on his own seed. It may never be possible to eliminate the disease totally in this manner, but the chances are that an effort made in this direction will bring about a material reduction in the extent of infection in succeeding crops.

SPECIAL CAUTION

Growers who wish to inoculate bean seed with nodule bacteria should not soak seed in a liquid culture of the bacteria, but should mix the culture with soil, sand, or some other carrier which can be dried and dusted onto the seed at the time of planting. The reason for this is that if disease spores or bacteria are present even on only a very few of the seed in the lot, the soaking method will tend to spread the germs over the rest of the seed and result in a general contamination of the entire lot, especially in view of the fact that when the seed is soaked the disease germs are liable to enter the opening in the seed coat of the bean and thus come into direct contact with the embryo plant, which can then hardly escape infection.

GRAIN SMUTS AND THEIR CONTROL

By H. P. Barss

Among the causes of loss to the Oregon grain farmer not any are more certain to take their annual toll than the smuts. These diseases are due to closely-related fungi, which, after infection has taken place, grow up inside the plant without producing any serious results until time for the head to form or the seed to mature. Then, in place of the healthy head or the healthy kernels, a black mass of microscopic, dust-like smut spores appears. The resulting loss comes not only from the loss of the yield from the diseased plants, but also from the dockage due to the abundant presence of spores in the threshed grain.

GRAIN SMUTS

Attention should be called to the fact that several distinct kinds and types of smut occur. The method of treatment will depend upon the type of smut and kind of grain involved. A brief description of the cereal smuts common in Oregon will precede the more detailed directions for control.

Corn Smut. This disease, which is different from all other types of grain smut and cannot be controlled by seed treatment, may attack almost any tender young growing part of the plant, particularly the young ears, and form there large swollen masses or boils completely filled with black smut spores. Since the disease is carried over in the soil, rotations are likely to be helpful. Some benefit may also be derived from early removal and burning of affected parts before the boils have burst. In Oregon the disease, while not rare, causes little damage in most localities, although in certain irrigated sections it appears to be pretty well established and on the increase.

Fig. 60. Loose smut of wheat.

Loose Smuts of Wheat and Barley. These two diseases, although similar in nature, are confined to their respective host crops. Neither disease causes very large losses in Oregon. The heads on diseased plants are transformed into powdery black masses of smut at blossoming time and the minute spores caught up by the breezes will sift into the healthy heads, where they may infect the young kernel, but interfere in no way with its maturing properly. These infected kernels, containing within them the germs of the smut, are normal in appearance, but the plants growing from them

will carry the disease and produce smutted heads. The typical appearance of loose smut of wheat is shown in Fig. 60.

On account of the fact that the germs of the loose smuts of wheat and barley are carried in the interior of the seed, external chemical treatment is of little or no avail. The modified Jensen hot-water treatment, however, will destroy the life of the tiny smut plant without materially injuring the seed. Hence, if it is impossible to secure seed of the desired variety from a field or locality where the disease is unknown, this method should be used, at least for next year's seed plot, which should be located at a distance from any infected field.

HOT WATER TREATMENT

(For loose smuts of wheat and barley.)

(1) Soak grain to be treated 4 to 6 hours in cold water.
(2) Taking a convenient amount of grain in a screen-lined basket or other container, plunge for one minute into a barrel of water kept at a temperature close to 120° F. to warm the seed up.
(3) Remove and plunge at once into another barrel where the water is kept at exactly 129° F. for wheat and 126° F. for barley. Keep wheat immersed for 10 minutes and barley for 13 minutes.
(4) Remove exactly on time and plunge into cold water to stop the action of the heat.
(5) Spread out in a thin layer to dry. If not to be planted at once, dry the seed out completely before sacking up again.

The important things to bear in mind are to keep the temperature constant and correct and to be exact in the time of treatment. A floating dairy thermometer should be used and more boiling water added from time to time as may be necessary, but the water must be thoroughly stirred so as to get a uniform temperature throughout. Too high a temperature or too long treatment in the hot bath will injure the grain, while too low a temperature or too short exposure will not kill the smut.

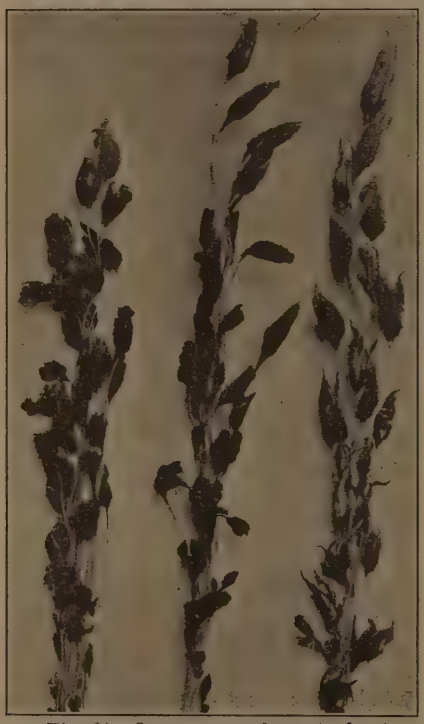


Fig. 61. Loose covered smut of oats.

Oat Smuts. There are two species of smut common on oats in Oregon. The loose smut is illustrated on the left in Fig. 61. The covered is shown in the right-hand specimen. In the latter sort the glumes are not so severely attacked, but there appears to be no great difference between the two species as far as infection, general development, and control methods are concerned. The infection arises from the spores contaminating the seed, the oats plantlets being invaded by the fungus as the seed germinates. The fungus grows up inside the plant and attacks the panicle, causing the spikelets to develop into a powdery black mass of smut spores. The disease is usually very successfully controlled by the formaldehyde method of seed treatment described later.

Bunt or Stinking Smut of Wheat and Covered Smut of Barley. These smuts are similar in their manner of development and in the methods used for their control, which are discussed in the following pages. The infection, which takes place as the seed germinates and the seedling is getting through the ground, may originate either from smut spores contaminating the seed or from spores contaminating the soil. The fungus grows up within the plant and into the heads, where, in the place of healthy kernels, masses of black smut spores develop. Fig. 62 shows infected heads of wheat, and Fig. 63 infected barley. The spores of wheat bunt have a disagreeable odor. They are compactly enclosed in a rather firm membrane forming what are known as smut balls where the healthy kernel should have been. They are usually plumper than the normal kernels and force the chaff to separate in an unnatural way so that the smutted heads may often be distinguished from some little distance.

SOURCES OF INFECTION

Contaminated Seed. Grain smuts are so prevalent in Oregon that there is little or no seed available which is absolutely free from smut spores. Even where a clean crop is raised, smut spores carried by the wind from diseased fields, perhaps many miles away, may easily lodge on the ripened heads and contaminate the grain. Seed treatment, therefore, becomes a necessity to kill the seed-borne spores, which otherwise will produce infection of the seedlings when the grain is planted.

Contaminated Soil. In Oregon much stinking smut infection comes from planting in the fall on ground which has received a "shower" of smut spores as a result of recent harvesting and threshing operations that have filled the air with these disease-producing particles. Summer-fallowed land gives the largest amount of trouble from this source because seed bed preparations here simply stir the blanket of spores into the upper layers of the soil, where they come in direct contact with the germinating plant and thus, no matter how thoroughly the seed may have been treated, some infection —often a good deal of infection—will occur.

Where land is plowed after the threshing season most of the blanket of smut spores will be turned under to a depth which is below that of the drilled-in seed, and infections from soil contamination will be fewer than in soil prepared merely by disking or harrowing.

When exposed to continued moist conditions smut spores

Fig. 62. Stinking smut or bunt of wheat.

on the surface of the ground or in the soil will germinate, and after a time, if there is no seedling grain to be attacked, the smut will die out. Therefore, if after a heavy rain in the fall, the ground remains in a well-moistened condition for perhaps six weeks, grain planted after this period will, as a rule, if carefully treated, develop little or no smut. This is probably the principal reason why late-planted fall wheat ordinarily produces a crop so much freer from smut than earlier plantings. Furthermore, the absence of the soil infection danger in spring-planted grain is due to the fact that fall and winter moisture has given abundant opportunity for the smut spores in the soil to die out.

Even where soil-infection cannot in the nature of things be avoided, the grower only invites additional smut losses by not treating to kill the smut on the seed. The final death blow to smut will, however, never be dealt, until, by breeding and selection, smut-resistant varieties of grain have been developed for each principal grain section. On this problem the Oregon Experiment Station and Federal Government are now working together and hopeful progress is being made.

RESISTANT VARIETIES

Mr. H. M. Woolman, Cooperating Field Assistant of the United States Bureau of Plant Industry, with headquarters at Corvallis, has within a period of two years tested out over a thousand strains and varieties of wheat for bunt resistance in plantings at Corvallis, Astoria, Moro, Hermiston, Union, and Medford. Several very promising resistant strains have appeared.

Fig. 63. Covered smut of barley.

Among these may be mentioned some of the Turkey selections made at the Moro Branch Station by Mr. D. E. Stephens. Several other highly resistant varieties have been found, among them one which thus far appears to be totally immune. Using these as parent stocks to furnish the element of resistance there is every reason to expect that progeny may be developed having also the highest commercial value. The final perfecting of well-adapted, smut-resistant grain varieties would be a tremendous, permanent advantage to Oregon, abolishing the need for chemical treatments and forever annihilating the otherwise apparently insuperable soil-infection problem.

CHEMICAL SEED TREATMENT

Care and Accuracy. Without care and accuracy in following the standard methods of treatment the grower runs the constant risk both of imperfect smut disinfection and of excessive injury to the ger-

minating power and vitality of the seed. Thousands of tests carried on at the Oregon Experiment Station in the last two years have shown that the methods given here are the safest and most effective yet worked out on a practical scale.

Cleaning. Before treating **clean the seed thoroughly** to remove broken and shriveled grain, smut balls, etc.

Rate of Seeding. Treated grain swells. The rate of seeding should be increased at least a fourth more than with untreated grain on this account.

Accurate Measurement. Avoid guesswork. Do not test the strength of the solution by color. Careful measurement is not difficult and it always pays.

Injury to Seed. A great deal of avoidable injury to germination has been traced to holding treated grain for days or weeks before planting, when not **thoroughly** dried out and ventilated. Hold to standard time for treatment and plant as soon as possible after treatment, preferably not later than twenty-four hours. When planted in the dust, treated seed should for safety be completely dried out (bone dry) before drilling in. Do not allow moist treated grain to freeze.

Recontamination. After treatment, the clean seed should not be brought into contact with sacks, floors, or machinery that has not been disinfected to destroy smut spores.

Treating Equipment, Etc. Large grain farmers will require especially constructed wooden tanks of considerable capacity. The small farmer may treat a sack at a time in barrels. Five-gallon cans are convenient for measuring the water used. A small pail, such as a lard bucket, can be used for measuring the bluestone after determining the average weight of bluestone it will hold. Never guess. Convenient drainboards should be constructed so as to let the solution drain back into the tank or barrel. It is often an advantage to have a slatted rack on which the grain butts, after being treated, may be placed to dry. They should be separated to permit air circulation on all sides and turned over occasionally. It must not be forgotten, however, that where treated grain has to be held some time before planting it should be spread out thinly on a disinfected floor and dried out **completely** before resacking. Neither the formaldehyde nor bluestone solutions lose strength in use or on standing.

Formaldehyde Method. This is the common method in use for oats and may also be used for wheat and barley when soil and temperature conditions are favorable for prompt germination.

FORMALDEHYDE FORMULA

1 pint formaldehyde (37% to 40% strength) to 40 gals. water (or 1 ounce—two tablespoons—to 10 qts. water).

Wet all the grain thoroughly either by sprinkling at the rate of one gallon of solution per bushel, or by pouring loose into the solution, or by soaking partly-filled and loosely-tied gunny-sacks for five minutes or so until thoroughly wet throughout, or run through a treating machine. Loose grain should be piled up after being treated and covered with canvas or sacks for two hours. Sacked grain should be drained and allowed to stand two hours. Then plant at once or spread out to dry and plant within a few hours.

Unless wheat is **absolutely** free from smut balls, it should be poured into the solution, thoroughly stirred, and the smut balls skimmed off, as the solution will not disinfect solid smut balls and any such on passing through the drill will break and recontaminate the seed as it runs out.

Dry Formaldehyde Method for Oats. This is a new and promising dry method of treating, which has given successful results wherever used on oats. Wheat may be injured by this method. It has not been tested in Oregon on barley.

Use 1 part of formaldehyde (37% to 40%) to 1 part of water.

Spread the grain on a clean floor. As the grain is shoveled from one pile to another, each shovelful is sprayed with a small quart hand sprayer (atomizer), held close to the grain, using 1 quart of solution to 50 bushels of oats.

When all are treated, pile in a heap, cover for four or five hours to retain fumes, then uncover, air out, and plant at once or in a few hours.

Bluestone-Lime Method. Bluestone (blue vitriol) is often injurious to oats. It is, however, the best method for wheat and barley where soil contamination is feared or where the soil and temperature conditions are not favorable for prompt germination. The coating of bluestone remaining on the grain serves to disinfect the soil slightly around the grain—although it will by no means eliminate soil infection entirely.

Bluestone when used alone is often very injurious to the vitality of wheat. This is partly due to the large percentage of kernels (often 80% or 90%) which have the skin broken over the germ by ordinary threshing methods. In order to neutralize the bluestone and thus prevent a large part of this injury it is necessary to dip the treated grain in a lime-water bath.

BLUESTONE FORMULA

1 pound bluestone (copper sulfate) to 5 gals. of water. (To this formula 1 lb. of salt is sometimes added.)

Suspend the chemicals in gunny sacking at top of the required amount of water in tank or barrel until dissolved completely, and stir the solution thoroughly before beginning the treatment, so as to get the solution uniform. Or to hasten the solution, the chemicals may first be dissolved in hot water. Do not use bluestone solution in metal containers, excepting copper, as it will corrode them.

The lime bath is made by slaking quick lime and adding water at the rate of ten gallons for every pound of quicklime.

Pour the grain slowly into the solution, stir thoroughly and skim off all smut balls. If the grain is absolutely free from smut balls it may be dipped into the solution in half- or third-filled gunny-sacks, which should be soused up and down to insure complete wetting of all the grain. Allow at least three to five minutes for the soaking, then drain for about fifteen minutes.

LIME BATH FORMULA

1 pound of quick lime to every 10 gals. of water. (Slake required amount of lime in usual manner and dilute according to formula.)

Then dip or pour the grain into the lime bath. The lime solution should be renewed whenever it loses strength, which can be determined by the blue color or by the fact that it will turn blue litmus paper red. Agitate the grain and allow the lime to act for at least three to five minutes. Remove the grain, drain, allow it to dry, and plant as soon as possible. If it cannot be planted promptly, it must be spread out and dried rapidly and completely before setting away.

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